The geology of the Klamath Mountains and Coast Ranges geologic provinces is described in greater detail in the sections below.

3.2.2.1 Klamath Mountain Province

At present, five major terranes of the Klamath Mountains are recognized, and several of these are subdivided into two or more geologic units. Each terrane is bordered by major faults that represent lines or sutures where plate fragments are joined (Harden, 1998).

A brief description of the rocks and terranes of the Klamath Mountains Province that underlie the Primary Assessment Area follows.

Western Jurassic Belt. The rocks of the Western Jurassic Belt underlie the eastern margin of the Primary Assessment Area. This belt represents the youngest accreted terranes within the Klamath Mountains Province. This belt includes the rock units of the Smith River subterrane (Galice Formation) as well as rocks that may be correlative with the Josephine Ophiolite.

- **Galice Formation.** The Galice Formation represents a long belt of metasedimentary rocks formed during the Jurassic period approximately 150 million years ago. The rocks of the Galice formation include marine slate (mildly slatey to phyllitic argillite), partially serpentinized peridotite, metagraywacke, stretched pebble conglomerate, and greenstone and metavolcanic Western Jurassic Belt breccia.
- **Josephine Ophiolite.** The Josephine Ophiolite represents a remnant of oceanic basement rocks that originated from a fragment of an oceanic plate that was thrust onto the North American continent during the Jurassic period. The rocks of the Josephine Ophiolite include, gabbro, pyroxinite, pillow basalt, serpentinite, and sequences of ultramafic rocks.

The Western Jurassic Belt also contains small pockets of intruded dioritic rocks that may be located within the Primary Assessment Area. To the west, the rocks of the Western Jurassic Belt are separated from the rocks of the Coast Ranges by a major fault (the South Fork Mountain Thrust fault).

Western Paleozoic and Triassic Belt. This belt is located to the east of the Western Jurassic Belt and has been subdivided into at least three separate geologic terranes. However, only one terrane (Rattlesnake Creek) occurs within the Primary Assessment Area.

- **Rattlesnake Creek Terrane.** The Rattlesnake Creek Terrane includes oceanic ultramafic rocks (i.e., gabbro), and metasedimentary rocks (i.e., argillite, phylitte, conglomerate and metachert) and vocaniclastic sediments and mixed volcanic and metasedimentary rocks.

In addition, the Western Paleozoic and Triassic Belt contains extensive intrusions of post-accretionary dioritic and pre-accretionary ultramafic-gabbroic plutonic rocks. However, it is uncertain if any of these materials occur within the Primary Assessment Area. The Western Paleozoic and Triassic Belt is primarily located along the eastern margin of the Smith River Hydrographic Unit and is separated from the Western Jurassic Belt by a complex network of thrust faults.

3.2.2.2 Coast Range Province

The majority of the Primary Assessment Area (greater than 80 percent) is located within the Coast Range Province (Figure 3.2-1). The rocks of the Coast Range represent oceanic crust that was accreted to the continent beginning in the mid-Jurassic period (approximately 140 million years ago). Similar to the Klamath Mountains Province, the assemblages of the Coast Range terranes are fault bounded and exhibit a sequential east to west accretionary pattern.

A brief description of the Coast Range terranes and associated rocks that underlie the Primary Assessment Area is presented below.

The Franciscan Complex. The Franciscan Complex includes three major belts (Eastern, Central, and Coastal). Cashman et al. (1995) and McLaughlin et al. (2000) describe the rocks of these belts and the geologic terranes in further detail. In general, the most abundant types of rock units found within these terranes consist of layered and interlayered sequences of marine sandstone (i.e., greywacke sandstone), schist, mélange, mudstone, shale, and other common rock types such as serpentinite, chert, and conglomerate, basalt and Coast Range ophiolitic rocks.

Because the Franciscan Complex includes rock units that vary greatly in lithology, structural style, and degree of metamorphism, the rocks in the complex are also described as belonging to a specific textural zone (Blake et al., 1967). It should be noted that some of the older geologic maps used to compile Figure 3.2-1 did not differentiate the various units and textural zones. Thus, unless a unit is specifically called out on the map, the textural zones listed below may be included in the areas mapped as Franciscan Complex (KJf) and Franciscan Complex Sandstone (KJfss).

The textural zones of the Franciscan Complex include the following:

- **Franciscan Mélange.** The Franciscan Mélange consists of discontinuous, resistant blocks of graywacke sandstone, chert, greenstone, and high-grade metamorphic rock in an intensely sheared, blue-gray shaley matrix. The texture of the unit may be related to mixing by either tectonic or sedimentary (mudslide) processes (Jordan, 1978).

- **Unmetamorphosed Franciscan Complex – Textural Zone 1.** Textural Zone 1 consists of fine-to coarse-grained graywacke sandstone with interbeds of siltstone, shale, and minor conglomerate. The rocks are olive to gray-green when fresh and weather to tan or gray-brown. Exposures are well-lithified and massive to thickly bedded. Subordinate rock types include chert, pillow basalt, and greenstone.

- **Semi-Metamorphosed Franciscan Complex – Textural Zone 2.** Textural Zone 2 consists of semi-schistose, lawsonite bearing graywacke sandstone and siltstone, similar to the rocks in Textural Zone 1. Platy foliation, visible in hand specimen, has developed, but original bedding is still present.

- **Undifferentiated Franciscan Complex.** Undifferentiated Franciscan Complex is mapped where the Franciscan has not been subdivided. It consists predominantly of fine- to coarse-grained dark gray to green graywacke sandstone and dark-gray shale. Subordinate amounts of red or green chert, conglomerate, pillow basalt, greenstone, and pods of serpentinized ultramafic rocks also occur within this unit.

- **South Fork Mountain Schist – Textural Zone 3.** The South Fork Mountain Schist is metamorphosed and sheared to the point where original bedding is no longer evident. The unit forms a sinuous belt of schistose metasedimentary and metavolcanic rocks next to the South Fork Fault, the unit's eastern boundary.

Overlap Assemblage. Sedimentary deposits that formed in a variety of marine to non-marine environments overlie the late Cenozoic to late Mesozoic accreted terranes of the Franciscan Complex. These deposits (the Late Cenozoic post-accretionary Overlap Assemblage) are partly similar in age to the Franciscan basement rocks. However, the rocks are considerably less deformed, unmetamorphosed, and less lithified than the rocks of the Franciscan Complex (McLaughlin et al., 2000).

The primary rock units that occur in the overlap assemblage within the Primary Assessment Area are represented by the formations of the Wildcat Group and, to a lesser extent, the Bear River beds (Figure 3.2-1). In general, the Wildcat Group consists predominantly of a sequence of weakly to moderately well lithified marine sandstone, siltstone, mudstone, and non-marine sandstones and conglomerates. The Wildcat Group overlies older basement rocks of the Franciscan Complex and middle rocks that have been assigned to the Bear River beds (interbedded siltstone, sandstone) (McLaughlin et al., 2000).

Other Quaternary and Tertiary Overlap Deposits. This section describes rocks that may occur within both the Klamath and Coast Range Provinces. These rocks include units of unconsolidated or weakly consolidated materials such as terrace deposits, alluvial and colluvial materials, coastal sediments, and unusual occurrences of post accretionary intrusive rocks (e.g., Coyote Peak diatreme).

- **Weathered Bedrock, Colluvium, and Soils.** An overlying mantle of weathered bedrock and colluvial deposits is ubiquitous in the Primary Assessment Area. Typically, the deposits are poorly consolidated, loose, and moderately to well drained. The material is usually thickest toward the axes of swales and drainages and thinnest on the steeper side slopes where it has been shed off by erosion and shallow landsliding. The composition and thickness of the colluvial deposits and associated soils is variable and is related to the makeup and slope gradient of the underlying bedrock.

  Thicker colluvium and soils typically reside in areas with gentle slopes where the bedrock is usually less indurated. Steeper slopes are generally covered by only a thin mantle (typically less than 3 feet thick) of colluvium. These slopes are usually underlain by hard, well-cemented materials (e.g., sandstone and siltstone), and the contact between the bedrock and colluvium is often sharp. The sharp contact is often accompanied by a permeability contrast between the two units that allows a seasonal perched water table to develop. The thin soil cover is a product of the inherent low rate of bedrock weathering and the steepness of the slope (which facilitates the shedding off of the unconsolidated surface material). The thin nature of the colluvial deposits overlying hard bedrock on the steeper slopes plays an important role in the style and distribution of shallow landslides and the potential effects of timber management.

- **Modern Alluvium.** Scattered concentrations of modern alluvium occur along stream beds and inner and upper floodplains throughout the Primary Assessment Area. The alluvial materials include boulders in creek bottoms, sand, pebbles and cobbly gravel in inner floodplains, and fine sand and silt loam in overbank deposits.

- **Stream Terrace Deposits.** Deposits of moderately to intensely weathered alluvium are scattered throughout the Primary Assessment Area. Mapable units have been noted in prominent terrace surfaces adjacent to Redwood Creek and remnants of former terrace deposits have been mapped on gently sloping hillslopes near Redwood Creek (Harden et al., 1981). Late Quaternary fluvial terraces are found along well developed major rivers such as the Mad, Eel, and Van Duzen rivers.
- **Coastal Plain Sediments.** Unconsolidated to weakly consolidated silts, sands, and gravels associated with minor amounts of organic-rich mud are located within the Primary Assessment Area along the coastal plain.
- **Landslide Deposits.** A number of landslide deposits and scars have been mapped within the Primary Assessment Area (Harden et al., 1981). Many of the more prominent landslides may be correlated to terranes underlain by fault zones and specific rock units (e.g., the Incoherent Unit of Coyote Creek in the Franciscan Complex).
- **Tertiary Intrusive Rocks.** The Central Belt of the Franciscan Complex contains limited occurrences of (alkalic) intrusive volcanic rocks of unusual mineralogical composition. These intrusive bodies correspond in age to the Oligocene epoch (approximately 35 million years before) and occur at two localities northeast of Arcata. One of these localities, known as the Coyote Peak diatreme, is located within the boundaries of the Primary Assessment Area.

3.2.2.3 Seismic Hazards, Faults, and Structural Relationships

Northern coastal California and the adjacent offshore area constitute one of the most seismically active areas in the State (Cashman et al., 1995). This entire area of northwest coastal California is subject to earthquakes on several onshore faults and falls within the Cascadia subduction zone, an area thought to be capable of great (magnitude 8 to 9) earthquakes (CDMG, 1996). The high level of tectonic activity in the region is also attributed to the proximity of the Mendocino triple junction (McKenzie and Morgan, 1969), an offshore boundary (located south of the Primary Assessment Area) which separates three major crustal plates and is the northern terminus of the San Andreas Fault (Figure 3.2-1).

Several moderately active crustal faults (e.g., the Little Salmon, Mad River, Trinidad, and Fickle Hill faults) are located near or within portions of the Primary Assessment Area. Faults that show evidence of recent (Quaternary) movement, and those faults that form the boundaries that separate the major belts, terranes, and subterranes of the Klamath Mountains and Coast Range Provinces are described below.

Although most of the faults strike northwest, they exhibit a range of orientations from shallowly dipping to vertical, and also represent different deformational episodes (Monsen et al., 1980, 1982). In addition, the orientations of the region's faults and geologic terranes often mark contacts between distinctly different rock units that, inturn, strongly influence area topography and drainage patterns. The faults that exhibit evidence of recent activity may also delineate potential geologic hazard zones (i.e., the occurrence of high ground accelerations resulting from earthquakes on nearby faults may directly or indirectly result in slope failures).

The following faults show no evidence of movement during the Quaternary period:

- **South Fork Fault.** The South Fork Fault (Irwin, 1974), a major east-dipping fault, separates and thrusts the rocks of the Klamath Mountains over the rocks of the Eastern Franciscan Belt of the Coast Range Province. Serpentinite, and a zone of tectonically mixed rocks have been mapped in areas (e.g., in the Redwood Creek basin) immediately above the South Fork Fault (Young, 1978).
- **Indian Field Ridge Fault.** The surface trace of the Indian Field Ridge Fault is found to the west of the South Fork Fault and is marked in places by narrow zone of unmetamorphosed pervasively sheared rocks (Cashman et al., 1995).
- **Grogan Mountain Fault Zone.** The steep northeast dipping Grogan Mountain Fault Zone delineates the channel of Redwood Creek. The zone is defined by an area of metamorphosed and pervasively sheared rocks and separates units of sandstone that mark distinct contrasts in surface topography (e.g., Incoherent Unit of Coyote Creek and Coherent Unit of Lacks Creek).
- **Bald Mountain Fault.** The Bald Mountain Fault lies to the west of the Grogan Fault and separates unmetamorphosed sandstone and mélange units to the west from the metamorphosed units (schists) of the Grogan Fault zone to the east (Strand, 1962).
- **Snow Camp Creek Fault.** The Snow Camp Creek Fault is the only major east-west trending fault in the Primary Assessment Area. The fault is located just south of Pardee Creek in the Redwood Creek basin and separates (Redwood Creek) schist units on the south from Franciscan sandstone and mélange units to the north (Harden et al., 1981).

The following faults exhibit evidence of recent movement and may be active:

- **Patricks Point Fault.** The Patricks Point Fault is a northeast-dipping thrust fault located below the prominent raised marine terrace cut into the Falor and Franciscan rocks at Patricks Point. The terraces are interpreted to record fault bend folding of the hanging wall of a deeply buried thrust above the fault. The length of the inclined segment of the Patricks Point terrace is about 2 kilometers (km). The fault bend fold model predicts this length should correspond with the total accrued slip on the buried fault (i.e., about 2.4 centimeters per year) (Carver and Burke, 1989).
- **Mad River Fault Zone.** The Mad River Fault Zone is a major zone of complex southwest-verging thrust faults located in the vicinity of the Mad River northeast of Arcata Bay. There are five principle faults in the Mad River Fault Zone including the Trinidad, Blue Lake, McKinleyville, Mad River, Fickle Hill, and numerous minor thrustfaults (e.g., Korbel and Falor Faults). The faults of this zone have been shown to displace strata in the late Pleistocene to Holocene Age (less than 2 million years) and are thus active (McLaughlin et al., 2000).
- **Freshwater Fault.** The Freshwater Fault is an east-dipping, high-angle reverse fault that decreases in dip to the north. Movement on this fault was thought to have preceded Wildcat deposition (Ogle, 1953), but recent studies show it to offset the Wildcat, suggesting late Cenozoic reactivation (Woodward-Clyde Consultants, 1980).

- **Little Salmon Creek and Yager Faults.** The Little Salmon Creek Fault is a moderately low-dipping southwest thrust fault located in the central Eel River basin south of Eureka. The fault zone cuts the surface and displaces Holocene (recent) Age strata. The nearby Yager Fault is interpreted to root in the same zone of thrusting as the Little Salmon Creek Fault (McLaughlin et al., 2000). Data on slip rate and estimates on earthquake recurrence intervals indicate that the Little Salmon Fault is active and capable of generating large earthquakes.
- **Russ and False Cape Fault Zones.** The Russ Fault Zone juxtaposes Miocene and younger strata (less than 24 million years) of the Eel River forearc basin (i.e., overlap assemblage) with coeval and older strata of the underlying accretionary complex. The distribution of surface and subsurface earthquakes strongly suggest that the Russ Fault is active at shallow depths (McLaughlin et al., 2000).

3.2.3 Geomorphology

3.2.3.1 Landform Development

The topography of the Primary Assessment Area is highly variable and consists of landforms ranging from steep terrane with deeply incised narrow drainages, to rolling landscape with less deeply incised drainage networks. As noted, the region has experienced high rates of Neogene uplift, deformation, and accompanying channel down cutting. Parallel to these processes, the area has experienced relatively high denudation rates and the upper reaches of many drainages have been sculpted over geologic time by repeated shallow landslides. At present, landslides are common throughout the Primary Assessment Area and continue to be a major force shaping the modern landscape.

In addition to hillslope mass wasting and erosional processes, a dominant factor controlling the variation in topography is the underlying rock mass and associated geologic structure. According to McLaughlin et al. (2000), rock masses larger than a few hundred meters in diameter tend to develop topographic forms related to the erosional and slope-stability properties of the constituent materials. These properties may be controlled by many factors, such as the structural state of the rock mass and orientation of layering. Rates of tectonic uplift may also play a role in the development of topographic form. However, geodetic work indicates that these rates tend to vary gradually and impact broad regional areas, rather than more localized areas (e.g., subunits of specific rock terranes located within individual HPAs) (McLaughlin et al., 2000).

The spatial variation in dominant rock units or geologic groups in the HPAs is evident in the expression of the local topography. In addition, the contact between the rock units and overlying soil is gradational and varies according to rock unit and topography. The major rock types and associated soils and landforms that may be found in the Primary Assessment Area follow:

- Well indurated sandstone rock masses weather to granular (sandy and silty) soil that is stable enough to form steep slopes. The stability and homogeneity of such soils and rock masses tend to result in steep, sharp-crested topography dissected by a regularly spaced array of straight, well-incised sidehill drainages (McLaughlin et al., 2000).

- Units containing unconsolidated and poorly indurated sandstone rock masses rapidly weather when disturbed and are highly unstable. These units tend to form a thick cover of sandy and silty soils, support only gentle hillslopes and poorly incised sidehill drainages, and crests tend to be rounded (Bond. J, NMFS, pers. comm.).
- Highly folded broken formations that also include zones of clayey sheared argillitic rock generally correspond to steep topography with generally sharp crests and well-incised but irregular sidehill drainages (McLaughlin et al., 2000).
- Units containing mélange with subequal amounts of sandstone and argillite or units that are predominantly made up of argillitic sequences that are highly folded and variably sheared generally have irregular, gently to moderately sloping topography that lacks a well-incised system of sidehill drainages (McLaughlin et al., 2000). Mélange areas typically support grassland prairie zones, which are susceptible to gully erosion, especially where overgrazing has increased runoff and road construction has disturbed the natural drainage channels. Although commercial timber grows on land underlain by mélange, many such areas were converted to grassland after timber harvesting and have not produced new timber growth (CDWR, 1982).
- Clayey rock masses, especially where sheared, weather to clayey soil materials. These clayey soils and bedrock are so weak that they can support only gentle hillslopes and poorly incised sidehill drainages, and crests tend to be rounded (Kelsey et al., 1995; McLaughlin et al., 2000).
- Well-indurated rock masses associated with the terranes of the Klamath Mountains Province result in very steep, sharp-crested topography. These units are typically overlain by thin soils and are dissected by straight, well-incised sidehill drainages.

3.2.3.2 Soils

The following section provides a brief description of the main soils types (series) in the Primary Assessment Area and is intended to supplement the geologic and geomorphologic descriptions presented above by providing additional background on how different soil series may relate to hillslope mass wasting and erosion in the region.

Soil is the product of the action of the climate and living organisms upon the parent material, as conditioned by time and relief. The interrelationships among the factors of soil formation are complex, and the effect of any one factor cannot be isolated and identified with certainty. Soils also have many characteristics that affect their behavior and response to various land uses. Specific physical and chemical properties such as permeability, susceptibility to erosion, and other features such as location of the water table, depth to bedrock, underlying geology, and slope influence how certain soils will react to various land management practices.

A soil survey is an inventory and evaluation of the characteristics and properties of soils in the survey area. It can be used to adjust land uses to the limitations and potentials of natural resources and the environment. The descriptions presented in this section are based on U.S. Department of Agriculture, Soil Conservation Service (SCS) soil surveys conducted in 1921, and CDF Soil and Vegetation Survey maps published in 1975. The information provided in the CDF soil-vegetation association maps is based on aerial photographs with limited ground truthing. Because much of the soil information in the Primary Assessment Area is out of date or incomplete, more comprehensive and up-to-date soil survey work is currently being conducted by the Natural Resource Conservation Service (NRCS), the successor to the SCS. However, this work is ongoing and the most recent NRCS soil survey data is not available at this time.

Area geology, along with the influence of climate, vegetation, and topography, resulted in the formation and distribution of a large number of different soil series within the Primary Assessment Area. This section, however, only presents descriptions of those soil series that have the largest aerial coverage in the Primary Assessment Area. Information on other less dominant soil series in the Primary Assessment Area is not provided due to the smaller total acreage covered by the series, discontinuity in area the soils cover, or incomplete soil information.

Six predominant soils series within the Primary Assessment Area are Hugo, Masterson, Melbourne, Larabee, Josephine, and Atwell. The remaining soils include those soils that are either unmapped or cover smaller discontinuous sections of the Primary Assessment Area.

The soils classification descriptions provided by NRCS and other agencies further define soils series descriptions according to physical and chemical properties including factors such as the following:

- Parent material the soil is derived from
- Texture
- Organic matter content
- Moisture retention characteristics
- Color
- Depth
- The type of terrane (slope) where the soil is found
- The soil’s surface erosion hazard rating

A summary of the physical and chemical characteristics of the predominant soils series in the Primary Assessment Area is presented below.

Hugo. Hugo soils are gray-brown at the surface, pale brown at the subsurface, and are 30 to 60 inches deep. The Hugo series consists of deep, well drained soils that formed in material weathered from sandstone, shale, schist, and conglomerate. Hugo soils are on uplands and occur on strongly dissected mountains with sharp, narrow ridges, and deep V-shaped drainages and have slopes of 9 to 75 percent. They range from near sea level to 4,000 feet elevation (NRCS, 1998). They range in texture from loam to clay loam. Surface erosion hazard is moderate to high (University of California, 1979). Hugo soils are associated with Melbourne soil and they are found throughout the Primary Assessment Area.

Masterson. According to the NRCS, Masterson soils are located on rolling to steep slopes at elevations of about 5,000 to 6,500 feet. However, Masterson soils are located at lower elevations in the Primary Assessment Area. The soils are dark brown at surface changing to yellow brown closer to bedrock. They formed in residuum weathered from mica schist and their depth to bedrock ranges from 20 to 40 inches (usually 30 to 40 inches). The amount of coarse fragments increases with increasing depth below a depth of 10 inches and average

35 percent to 55 percent of the volume. (NRCS, 1998). Masterson soils are most abundantly found in the Redwood Creek and Interior Klamath HPAs.

Melbourne. Melbourne soils are on foothills, hillsides, and ridge tops at elevations of 200 to about 1,200 feet. Slopes are zero percent to 65 percent. The soil formed in residuum colluvium from siltstone and fine-grained sandstone (NRCS, 1998). Melbourne soils are brown at the surface, dark brown in the subsurface, 30 to 60 inches deep, and are classified as loam to clay loam. Surface erosion hazard is moderate on slopes less than 50 percent (University of California, 1979). Melbourne soils are associated with Hugo soils and they are found throughout the Primary Assessment Area.

Larabee. Larabee soils occur on moderately steep to steep, well dissected uplands under forest vegetation at elevations up to 2,000 feet. Larabee soil is typically deep, well drained, and fine grained, with a high silt content throughout the profile. Larabee soil is derived from soft sedimentary rocks of the California north coast range and is found mostly within the Mad River, Humboldt Bay, and Eel River HPAs.

Josephine. The Josephine series consists of deep, well drained soils (gravelly loam) that formed in moderately fine textured colluvium and residuum weathered from sedimentary, metamorphosed sedimentary, and volcanic rocks. Josephine soils are on broad ridge tops, toeslopes, footslopes, and side slopes of mountains. Elevations are 200 to 5,500 in California. Slope gradients dominantly are 35 percent to 60 percent but range from 2 percent to 75 percent. Josephine soils can be found to a depth of 59 inches and range from dark brown at surface to brown, reddish brown and yellowish brown at depth (NRCS, 2000).

Atwell. Atwell soils are important because they are extremely erodible (University of California, 1979). These soils formed in colluvium from sheared graywacke sandstone and shale. Atwell soils occur in mountainous terrane at elevations up to 3,000 feet. They occupy concave to irregular, unstable slopes in areas of high drainage density. Soil slips, landslides, seeps, and springs are common in Atwell soils. Slope gradients are from 15 percent to 50 percent and colors vary from grayish brown, to dark grayish brown and olive brown to light yellowish brown (NRCS, 2001). Atwell soils are known to occur in association with the Mad River Fault Zone and the Grogan Fault (Redwood Creek), and they likely occur in other localities of the Primary Assessment Area as well.

3.2.3.3 Landslide Classification and Landslide Prone Terrain

Many types of hillslope mass wasting occur within the Coast Range and Klamath Mountain Provinces. As previously mentioned, landslides are common throughout the Primary Assessment Area. Intense and prolonged rainfall events combined with area geology, geomorphology, and timber harvesting activities often result in conditions that are highly susceptible to excessive erosion and landslides, especially when high antecedent groundwater conditions exist. Types of landslides in the Primary Assessment Area are described below based on the classifications in Crunden and Varnes (1996) and CDMG (1997) with modifications to suit the conditions present in the area.

Shallow-Seated Landslides. Shallow-seated landslides are generally confined to the overlying mantle of colluvium and weathered bedrock, although in some instance may involve competent bedrock as well. Most shallow landslides are rapid events and commonly leave a bare unvegetated scar after failure.

- **Debris Slides.** Debris slides are characterized by a process whereby unconsolidated rock, colluvium, and soil have failed rapidly along a relatively shallow failure plane. In most instances the depth of failure is less than 10 feet. In some instances, however, a debris slide may extend deeper and incorporate some of the underlying competent bedrock. Debris slides often form steep, unvegetated scars in the head region and irregular, hummocky deposits in the toe region. Slide debris often overrides the ground surface near the toe. Debris slides may exist individually or coalesce to form a larger landslide complex. Slides often continue to move for several years following initial failure. Most natural debris slides are triggered by elevated pore water pressures resulting from high intensity and/or long duration rainfall or from being undercut by stream erosion. The occurrence of high ground accelerations resulting from earthquakes on nearby faults may also result in shallow slope failures either directly or indirectly by reducing soil strength and altering the groundwater regime. In many managed watersheds, a common cause of debris slides is thick, over-steepened road fill associated with old roads, skid trails, and landings.

- **Debris Flows/Torrents.** Debris flows and debris torrents are characterized by long stretches of bare soil and generally unstable channel banks that have been scoured by the rapid movement of debris. Failure typically begins as a debris slide but quickly mobilizes into a flow or torrent as material liquefies, traveling rapidly downslope. These landslides occur most commonly on very steep slopes at or near the axis of small swales or stream channels. As a debris flow/torrent moves through first and second order channels, the volume of material may increase to a much greater size than the initial failure. It is not unheard of for a large debris torrent to deliver more than 10,000 cubic yards of sediment to a stream channel.

- **Channel Bank Failures.** Channel bank failures are defined as small shallow debris slides that occur along the banks of stream channels. Such failures are a result of undercutting of the stream bank by stream incision or stream widening. Large channel bank failures that extend far up an adjacent hillslope may become difficult to distinguish from debris slides. Because such failures are relatively common along streams they have been classified separately from the other failures.

- **Rock Falls.** Rock falls are characterized by catastrophic failure of relatively steep rock slopes or cliffs along a surface where little or no shear displacement takes place. Generally rock debris accumulates at the toe of the slope. Rock falls are relatively uncommon in the Primary Assessment Area.

Deep-Seated Landslides. Deep-seated landslides typically have a basal slip plane that extends into bedrock. Most deep-seated failures move incrementally; catastrophic failure is relatively rare. Active slides are typically vegetated with trees and/or grass.

- **Translational/Rotational Rock Slides.** Translational/rotational rockslides are characterized by movement of a relatively intact slide mass with a failure plane that is relatively deep when compared to that of a debris slide. The slide plane typically extends below the colluvial layer into the underlying and more competent bedrock. The slides often have a distinct toe at the base of the hillside and undercutting of the toe of the slope by streams plays a key role in their long-term stability. Translational/rotational rock slides are identified by a broad arcuate headscarp and a series of mid-slope benches on what is otherwise moderately to steeply sloping terrane. Sag ponds, hummocky topography, and springs and patches of wet ground may be present. Commonly the landslide consists of several smaller slide blocks that coalesced together to form the larger landslide complex. Lateral scarps between the individual landslide blocks are often poorly defined, in part due to the low rate and/or infrequent movement of the slide mass. Differential movement between individual slide blocks is common. Where slide movement is most active, drainage networks and stream channels are shallow and generally poorly to moderately defined. Movement is most apparent in the upper portion of the hillside and less apparent near the toe. Steep main scarps, secondary internal slide scarps, and toe slopes may be subject to debris sliding.

- **Earthflows.** Earthflows are characterized by a relatively large semi-viscous and highly plastic mass resulting in a slow flowage of saturated earth. Most earthflows are composed of a heterogeneous mixture of fine-grained soils and rock. Earthflows may range from less than 1 acre to hundreds of acres. The depth of failure is varied but typically greater than 15 feet and the degree of activity is varied - many earthflows are dormant while others exhibit seasonal creep in response to high rainfall. Rapid movement of such failures is rare. Ground displacement is generally slight, and catastrophic failure of the slope is unlikely. Slide materials erode relatively easily, resulting in gullying and irregular drainage patterns and may be reactivated in response to removal of toe support, high rainfall events, and possibly by large seismic events. Because of the seasonal movement associated with some of these slides, earthflow areas are often unable to support timber stands. Small earthflows may be influenced by poor road drainage across the toe of the slide.

Landslide-Prone Terrains. Both deep and shallow landslides occur within the Primary Assessment Area, with shallow landslides most common on slopes steeper than 60 percent to 70 percent. In general, steep streamside slopes, inner gorge slopes, steep headwall swales, and breaks-in-slopes have been identified as areas with greater potential for producing shallow landslides compared to adjacent slopes. Landslides are also more frequent in areas of convergent slope form where surface and ground waters tend to concentrate and where colluvial soils tend to be thickest.

The most prevalent landslide-prone terrains in the Primary Assessment Area are:

- **Steep Streamside Slopes.** Steep streamside slopes are defined as steep slopes located immediately adjacent to a stream channel, and generally formed, over time, by coalescing scars from shallow landsliding and stream erosion. These slopes typically exceed 65 percent gradient where stream incision has undercut the toe of the slope, and descend directly to streams without intervening topographic benches. Preliminary landslide inventories in the Primary Assessment Area indicate that roughly 60 percent to 90 percent of all shallow landslides initiate on steep streamside slopes. All steep streamside slopes show evidence of modern landslide processes (less than 50 years old) when slopes are examined on a sub-basin level.

- **Inner Gorges.** An inner gorge is a subset of steep streamside slopes where a more-or-less distinct break-in-slope separates steeper "inner gorge" slopes below the break-in-slope from lower gradient slopes above the break. The steep streamside slopes classification includes inner gorge slopes as well as those steep slopes where a distinct break-in-slope is absent.

- **Headwall Swales.** Many shallow landslides occur within headwall swales upstream of Class III watercourses, where convergent topography forces both the accumulation of thick soils and the concentration of shallow subsurface runoff along the axis of the valleys. Headwall swales are defined as areas of narrow, steep, convergent topography (swales or hollows) located at the heads of Class III watercourses (i.e. an unchanneled swale extending upstream of a watercourse) that have been sculpted over geologic time by repeated debris slide and debris flow events. The sideslopes leading into the swale are typically greater than 70 percent. Slopes are often smooth to slightly irregular, unbroken by benches. Swales often have an inverted teardrop or spoon shaped appearance. Seasonal seeps, springs and wet areas may exist within the axis of the swale toward the base. The soil and colluvium depth is often much deeper within the axis of the swale than on the adjoining side slopes. The surface expression of the swale may be distinct to subdued. The width of headwall swales is highly variable ranging between 30 and 100 feet.

3.2.4 Geology, Topography, and Geomorphology of the HPAs and Rain-on-Snow Areas

This section provides a brief description of the geology, topography, and geomorphology of the 11 HPAs. This general information is provided because more detailed and specific information on the individual HPAs is not available at this time. Green Diamond is in the process of conducting a Hillslope Mass Wasting Assessment and Landslide Inventory on its fee-owned lands within the Primary Assessment Area. The assessment is currently scoped as a 5-year effort and the resulting data will be used to fill in the gaps on site geology and hillslope mass wasting within the individual HPAs. HPAs encompassing complete drainage areas are referred to as “hydrologic units,” whereas those encompassing partial or multiple watersheds are referred to as “hydrographic areas.”

3.2.4.1 Smith River Hydrographic Region

The Smith River Hydrographic Region is approximately 182,000 acres. Bedrock underlying the hydrographic region predominantly consists of Central Belt Franciscan Complex rock with areas of Klamath Mountains bedrock along the eastern margin of the region. Faults in the region include the inactive South Fork Fault, which separates the Franciscan bedrock from the Klamath Mountains bedrock, and a complex network of thrust faults within the Klamath Mountains geology.

Scattered, poorly consolidated remnants of Miocene marine sandstone, siltstone, and conglomerate deposits (Wimer Formation) overlie the Franciscan bedrock on ridges, approximately 5 miles inland and at elevations of 1,200 to 1,600 feet above mean sea level (ASL). There are also remnants of continental deposits of sandstone and conglomerate, of similar age, on ridges at slightly higher elevations, near the Wimer Formation deposits. The coastal section of the hydrographic unit is dominated by the Smith River Plain, an elevated marine terrace where an abrasion platform of Franciscan rocks is almost entirely covered with a blanket of marine siltstone, shale and unconsolidated sands of Pliocene and Pleistocene age (Battery Formation). Pleistocene to Holocene river terrace deposits, flood plain deposits, and dune sands also cover large portions of the Smith River Plain. Unconsolidated Pleistocene to Holocene river terrace and flood plain deposits can also be found at various locations along stream and river channels (Ristau, 1979; Davenport, 1982-84; Wagner and Saucedo, 1987) within the unit.

Within this HPA, Central Belt Franciscan bedrock composed of Undifferentiated Franciscan Sandstone underlies Green Diamond's northern and southwestern ownership and Klamath Mountains bedrock composed of serpentinite, gabbro, metavolcanics, and metasedimentary rocks underlies the southeastern ownership (Figure 3.2-1).

The topography of the Smith River Hydrographic Region is highly variable, but, in general, is relatively steep and sharp-featured compared to other HPAs. Pleistocene and Holocene landslide deposits cover portions of the Franciscan bedrock at numerous locations. Published landslide maps indicate that both shallow and deep-seated landslides exist throughout this HPA with debris slides and disrupted ground present on many of the steeper slopes (CDMG, 1999). The inherently weak serpentinite of the Klamath Mountains bedrock is also particularly prone to landslide processes, but this geologic unit is only a small portion of the Primary Assessment Area in this hydrographic region.

3.2.4.2 Coastal Klamath River Hydrographic Region

The Coastal Klamath River Hydrographic Region is approximately 108,000 acres. The area is predominantly underlain by Central Belt Franciscan Complex bedrock with Klamath Mountains bedrock underlying a narrow strip along the eastern margin of the unit. The Central Belt Franciscan Complex is generally described as meta-sandstone. Klamath Mountains bedrock in the HPA is composed of Josephine Ophiolite intrusive and extrusive volcanics, which includes partially to completely serpentinized ultramafic rocks, gabbro, diorite, pillow lava and breccia. The inactive South Fork Fault separates the Franciscan rocks from the older rocks of the Klamath Mountains geologic province (Figure 3.2-1).

The topography of the Coastal Klamath Hydrographic Region is highly variable, but in general is relatively steep and sharp featured. Landslide processes in the unit are dominated by shallow debris slides and debris flows, based on Green Diamond's preliminary landslide inventory data from this area. These landslides tend to be prevalent on steep streamside slopes along Class I and Class II watercourses and to a lesser extent in the headwall areas of Class III watercourses. Sediment delivered to watercourses from shallow landslides is considered a significant portion of the sediment budget for this hydrologic unit. Deep-seated landslides are relatively uncommon within this unit, although they do exist, as is indicated by CDMG-published landslide maps and Green Diamond's preliminary landslide inventory data. The inherently weak serpentinite of the Klamath Mountains bedrock is particularly prone to landslide processes, but this geologic unit comprises only a small portion of the Primary Assessment Area in this HPA.

3.2.4.3 Blue Creek Hydrologic Unit

The Blue Creek Hydrologic Unit is approximately 80,000 acres. The majority of the Blue Creek Hydrologic Unit (i.e., the central and eastern areas of the unit) is underlain by Klamath Mountains bedrock. The bedrock in the remaining sections of the unit (i.e., the southwest area of the unit) primarily consists of Franciscan Complex rocks (Figure 3.2-1). The inactive South Fork Mountain Fault separates the Coast Ranges Province from the Klamath Mountains Province.

The Primary Assessment Area within the Blue Creek Hydrologic Unit is primarily underlain by Franciscan Complex rocks. From east to west, bedrock within the hydrologic unit consists of small patches of partially to completely serpentinized ultramafic bedrock of the

Josephine Ophiolite, the South Fork Mountain Schist unit of the Franciscan Eastern Belt and the meta-sandstone and mudstone of the Franciscan Central Belt.

The topography of the Blue Creek Hydrologic Unit is generally characterized by steep to very steep terrane, and is similar to the steeper topography within the Coastal Klamath HPA. Elevations and slope gradients increase toward the east of the unit due to higher concentrations of massively bedded Franciscan Complex sandstone, and the occurrence of the more resistant metasedimentary and ultramafic rocks of the Klamath Mountains.

Specific data on landsliding in this hydrologic unit is unavailable at this time. However, based on an analysis of existing geologic maps, it appears that landslide processes in this hydrologic unit are dominated by shallow debris slides and debris flows in the Klamath terranes, and there is a potential for deep-seated landslides within Coast Range terranes.

3.2.4.4 Interior Klamath River Hydrographic Region

The Interior Klamath River Hydrographic Region is approximately 128,000 acres. Bedrock in the region is primarily composed of the Coast Ranges Franciscan Complex, with Klamath Mountains bedrock present in limited areas at the eastern margin of the region. The inactive Coast Ranges Fault separates Franciscan Complex Central Belt sandstone from Franciscan Complex Eastern Belt South Fork Mountain Schist, and the inactive South Fork Fault separates the Coast Ranges Province from the Klamath Mountains Province geology.

Most of the Primary Assessment Area within this HPA is underlain by the Franciscan Complex bedrock. The bedrock in this HPA is roughly divided between Central Belt sandstone and Eastern Belt South Fork Mountain Schist. Central Belt meta-graywacke is also located in smaller areas of the HPA, and limited areas of the eastern margin of the region are underlain by Klamath Mountains volcanics and metavolcanics.

Specific data on landsliding in this hydrographic region is unavailable at this time. However, based on an analysis of existing geologic maps, it appears that landslide processes in this hydrographic region are dominated by shallow debris slides and debris flows in the Klamath terranes, and there is a potential for deep-seated landslides within Coast Range terranes.

3.2.4.5 Redwood Creek Hydrologic Unit

Substantial geologic mapping and research has been done in the Redwood Creek area (Nolan et al., 1995). As a result, the geology, landform development, and hillslope mass wasting characteristics of this hydrologic unit are probably the best understood of all of the HPAs that make up the Primary Assessment Area.

The Redwood Creek Hydrologic Unit is approximately 188,000 acres. The Redwood Creek Hydrologic Unit is located entirely within the Coast Ranges geomorphic province. Most of the Primary Assessment Area in this unit is underlain by the Redwood Creek Schist. Much smaller sections of the Primary Assessment Area, located to the east and southeast, are underlain by the Incoherent Unit of Coyote Creek, and the Coherent Unit of Lacks Creek. A small section located at the southern tip of the hydrologic unit is underlain by the Sandstone and Mélange of Snow Camp Mountain. Coastal plain and marine terrace sediments are located in the northern coastal area of the unit. These sediments are mainly composed of unconsolidated to slightly consolidated sands, silts, and gravels, and may be as much as 300 feet thick.

Each of the major bedrock units in the Redwood Creek Hydrologic Unit is set apart from one another by a series of major northwest trending faults. The most notable of the faults found in this unit is the Grogan fault, which defines the channel of Redwood Creek and separates the Redwood Creek Schist from the Incoherent Unit of Coyote Creek. Other notable faults are the Indian Field Ridge Fault, which separates the Incoherent Unit of Coyote Creek from the Coherent Unit of Lacks Creek, and the Snow Camp Creek Fault, located at the southern tip of the hydrologic unit, which separates Redwood Creek Schist from the Sandstone and Mélange of Snow Camp Mountain.

Many hillslopes in the Redwood Creek basin are unstable and highly susceptible to mass-movement failure because of the steepness of the terrane and the low shear strength of much of the underlying saprolite and residual soil. (This is especially true in the Incoherent Unit of Coyote Creek, although shallow landslides also exist in the unit). According to Colman (1973), at least 36 percent of the basin shows landforms that are the result of active mass movements or that are suggestive of former mass-movement failures. Complex associations of rotational slumping, translation, and earthflows are the most visually obvious forms of mass movement in the Redwood Creek basin. Some have clearly defined margins, but many gradually merge with less active areas of soil creep. On many earthflows, grass, grass-bracken-fern, and grass-oak prairie vegetation dominate in marked contrast to the mature coniferous forest or cutover land on more stable slopes.

Several lithologies occur within the Redwood Creek Schist and the geomorphic expression of the different schist units is variable. Slopes underlain by the Redwood Creek Schist have gently convex profiles and side-slope gradients commonly range from 20 percent to 40 percent. Both the Redwood Creek Schist and the South Fork Mountain Schist exhibit knobby topography in areas where greenstone units of tectonic blocks are included in the schist. Shallow, incised streams are a typical drainage feature of schist slopes (Cashman et al., 1995). In addition, some evidence of deep-seated, slow moving, landslide deposits have been identified in road cut exposures in the schist units (Cashman et al., 1995).

The sandstone and mudstone of the Coherent Unit of Lacks Creek have a distinct geomorphic expression. Sharp ridges, steep slopes, and narrow V-shaped tributary canyons are characteristic of the landscape developed on these relatively resistant rocks. Slopes have straight to gently concave profiles, and slope gradients commonly range from 30 percent to 50 percent. In the Coherent Unit, streamside debris slides and debris avalanches are common in the inner gorges of tributaries (Cashman et al., 1995). In contrast to the steep terrane of the Coherent Unit, the bedrock of the Incoherent Unit of Coyote Creek forms a subdued rolling landscape having less deeply incised drainage networks and few high points and knobs formed by resistant rock types. Earthflows are preferentially developed in this unit, as are streamside debris slides along inner gorges.

Rocks in the Grogan Fault Zone that are intermediate in texture and degree of metamorphism between the Redwood Creek Schist and the sandstone and mudstone units. The geomorphic expression of this unit is similar to that of the Incoherent Unit of Coyote Creek, and streamside debris slides are concentrated along linear zones of sheared rocks parallel to the Grogan Fault (Harden et al., 1981).

The landscape developed on the Sandstone and Mélange unit of Snow Camp Mountain is generally more hummocky than other hillslopes in the Redwood Creek Hydrologic Unit. However, parts of the Snow Camp Mountain unit are underlain by massive sandstone and display steep slopes, prominent ridges, and V-shaped valleys, in contrast to the more rolling hummocky hillslopes underlain by mélange. Tectonic blocks of greenstone and chert form prominent knobs and summits (Cashman et al., 1995). As in the Coherent Unit of Lacks Creek, streamside debris slides and debris avalanches are common in the inner gorges of tributaries and in the steeper areas of the unit underlain by massive sandstone.

3.2.4.6 Coastal Lagoon Hydrographic Region

The Coastal Lagoons Hydrographic Region is approximately 54,000 acres. Bedrock in the region includes the Redwood Creek Schist, the Sandstone and Mélange of Snow Camp Mountain, and Undifferentiated Central Belt Franciscan Mélange, the Patrick's Point meta-graywacke unit, and younger marine and non-marine terrace deposits near the coastline.

These geologic units are generally structurally bounded by northwest trending thrust faults and high angle faults. Broad northwest trending anticlines and synclines are also mapped within the hydrographic region.

The topography of the hydrographic region is moderately steep, except in the younger terrace deposits and in the area of the lagoons near the coastline. Preliminary Green Diamond landslide inventory results indicate that both shallow and deep-seated landslides exist throughout the Coastal Lagoons hydrographic region.

3.2.4.7 Little River Hydrologic Unit

The Little River Hydrologic Unit is located within a coastal watershed with a drainage area of approximately 30,000 acres. From east to west, the bedrock of the unit is composed of Redwood Creek Schist (along the eastern margin), Sandstone and Mélange of the Snow Camp Mountain, and Undifferentiated Central Belt Franciscan Bedrock. Quaternary deposits are found near the mouth of the watershed located at Moonstone Beach (several miles south of Trinidad, California). The Snow Camp Mountain geologic unit is composed of hard, intensely folded graywacke sandstone and siltstone that grades into sheared mélange. The Redwood Creek Schist is mostly composed of hard, fine-grained quartz-mica schist, which includes or grades locally into bodies of semi-schist, slate, meta-conglomerate, and meta-chert (Kilbourne, 1983-85; Harden et al., 1981). The Undifferentiated Central Belt is composed of sandstone and mudstone. The Quaternary deposits are composed of poorly consolidated interbedded clays, silts, sands, and gravels.

Marine terrace deposits of late Pleistocene and Holocene Age cover bedrock surfaces on wave-cut benches, within about 3 miles of the coastline, and up to 500 feet ASL, near the mouth of Little River. The terrace deposits are composed of unconsolidated to slightly consolidated silts, sands, and gravels, including old dune sands. Holocene alluvium and flood plain deposits cover the valley floor, nearly one-mile wide, in the area downstream from Crannell (Ristau, 1979; Kelley, 1984).

The inactive Bald Mountain Fault is located between the Snow Camp Mountain and Redwood Creek Schist geologic units and the active Trinidad Fault separates these relatively young strata from the adjacent Franciscan Mélange.

The hydrologic unit is generally characterized by moderate- to high-relief hillslopes, except for the area from the Crannell town site to the mouth of the river at Moonstone Beach. Published landslide maps and Green Diamond's preliminary landslide data indicate that both shallow and deep-seated landslides exist throughout this HPA. The Franciscan mélange is particularly susceptible to earth flows, and the younger, sandy bedrock, which is susceptible to slumping and rotational slide movement, is relatively highly erodible.

3.2.4.8 Mad River Hydrographic Region

The Mad River Hydrographic Region is approximately 120,000 acres. Bedrock within the Mad River Hydrographic Region is composed mostly of Central Belt Franciscan Complex and Quaternary – Tertiary Overlap deposits juxtaposed by the Mad River thrust fault system. The Primary Assessment Area within this hydrographic region is composed of the three major geologic units mentioned above.

Topography in the region is relatively steep and mountainous, but fairly extensive lowlands are present from the mouth of the river and upstream to the Mad River Fish Hatchery, near the town of Blue Lake.

Central Belt Franciscan Complex is composed of broken formation (schist, greywacke sandstone, shale, conglomerate, chert, pillow basalt, and greenstone) and mélange (primarily composed of discontinuous bodies of hard greywacke sandstone, chert, greenstone and pillow basalt in a weak, pervasively sheared claystone matrix). However, mapping of the units has not been systematic and consistent in all parts of the watershed. In much of the area, the Franciscan units have not been separately identified, and the rock is simply mapped as Undifferentiated Franciscan.

Quaternary – Tertiary Overlap deposits include the Falor Formation, which is generally described as poorly cemented clay, silty clay, and pebbly sandstone and fine-grained sandstone with pebbly stringers (James, 1982). The Falor Formation is correlated to the upper section of the Wildcat Group (James, 1982). Other Quaternary – Tertiary Overlap deposits include marine terraces, fluvial terraces, dune deposits, and Holocene alluvium and beach deposits.

Pleistocene to Holocene marine terrace deposits cover the bedrock surfaces on wave-cut benches within about two miles of the coastline, and up to 260 feet above sea level. These deposits are composed of slightly consolidated silts, sands and gravels, which have been uplifted and offset by subsequent fault movements (Kelley 1984; Kelsey and Carver 1988). These deposits cover the bedrock at various locations adjacent to the present stream and river channels, but at higher levels than the active channel deposits. As many as six separate terrace levels have been identified at some locations, with progressively older terrace deposits at correspondingly higher levels. These deposits are composed of unconsolidated, poorly sorted sands, gravels, and boulder conglomerates. Fluvial terrace deposits are most extensive adjacent to Lindsay Creek in the Fieldbrook area and adjacent to the Mad River at Blue Lake and Butler Valley (Kelley, 1984; James, 1982; Kilbourne, 1983-85).

Ancient dune sand deposits, of Pleistocene to Holocene age, overlie the bedrock up to 4 miles from the present coastline, and up to 620 feet ASL. These deposits are composed of unconsolidated fine to course grained sand (Kelley, 1984). The ancient dune sands may be part of the Hookton Formation located south of the area covered in this study. These materials are extremely erodible where they are exposed, and they are subject to slumping where slopes are undercut.

Holocene alluvium, flood plain deposits, and beach deposits are present in active stream and river channels, in valley bottoms, and on the coastal plain. They are composed of poorly sorted, unconsolidated mixtures of boulders, gravel, sand, silt, and clay (James, 1982; Kelley, 1984; Kilbourne, 1983-85; Ristau, 1979). These deposits are reworked by meandering and shifting stream channels, especially during the infrequent large flood events. The sediment progressively migrates downstream, with new material being added at multiple points along the channels by erosion and landslide movement. Some of that new material is transported out to sea or removed by gravel mining.

Pleistocene to Holocene marine terrace deposits cover the bedrock surfaces on wave-cut benches within about 2 miles of the coastline, and up to 260 feet ASL. These deposits are composed of slightly consolidated silts, sands, and gravels, which have been uplifted and offset by subsequent fault movements (Kelley, 1984; Kelsey and Carver, 1988).

Published landslide maps indicate that both shallow and deep-seated landslides exist throughout this HPA. Deep-seated rotational/translantional landslides and earthflows are common in the Franciscan Mélange. Younger bedrock in the Primary Assessment Area is generally described as poorly consolidated, uncemented, interbedded sands, silts, clays, and gravels. These materials are extremely erodible, and they are very susceptible to slumping and rotational slide movement.

3.2.4.9 North Fork Mad River Hydrologic Unit

The North Fork Mad River Hydrologic Unit is approximately 31,000 acres. Bedrock within the North Fork Mad River Hydrologic Unit is composed mostly of Central Belt Franciscan Complex with Quaternary – Tertiary Overlap deposits in the southwest section of the unit juxtaposed by the Mad River thrust fault system.

From east to west, the Franciscan bedrock within the Primary Assessment Area is Redwood Creek Schist along the east margin, Sandstone and Mélange of Snow Camp Mountain and Undifferentiated Franciscan Complex rocks, also identified as Broken Formation rock on the west side of the Undifferentiated Franciscan (McLaughlin et al., 2000) and Quaternary – Tertiary Overlap deposits (Figure 3.2-1). The northwest-trending, northeast-dipping Bald Mountain Fault separates rocks of the Redwood Creek Schist and the Snow Camp Mountain unit in the east portion of the watershed.

The topography of the unit is relatively steep and mountainous, similar to the rest of the Mad River watershed. Similar to the other Mad River hydrographic areas, both shallow and deep-seated landslides exist throughout this HPA. Deep-seated rotational/translational landslides and earthflows are common in the Franciscan mélange. Younger bedrock in the Primary Assessment Area is generally described as poorly consolidated, uncemented, interbedded sands, silts, clays, and gravels. These materials are extremely erodible, and they are very susceptible to slumping and rotational slide movement.

3.2.4.10 Humboldt Bay Hydrographic Region

The Humboldt Bay Hydrographic Region is approximately 139,000 acres. The Humboldt Bay Hydrographic Region includes Quaternary – Tertiary overlap deposits and Quaternary age alluvium, with Yager Terrane near the southern boundary of the region and Central Belt Franciscan Complex bedrock under the eastern quarter of the region.

The bedrock in this region includes both Quaternary – Tertiary overlap deposits and the Central Belt Franciscan mélange. The overlap deposits within the Primary Assessment Area include the Wildcat Group, which is composed of moderately consolidated, poorly cemented, weak siltstone, claystone, and fine sandstone, as well as the Falor Formation. These strata were deposited on an erosional surface of Franciscan and Yager Formation rocks, and they have been subsequently eroded, faulted, folded, and partly covered with younger sedimentary rocks. The Central Belt Franciscan Mélange is described as a weak, pervasively sheared claystone matrix, which encloses various-sized blocks of hard sandstone, greenstone, metavolcanic rock, serpentinite, chert, and schist. Some of the different lithologic blocks in the mélange are large enough to be mapped separately at a large enough scale.

The Fickle Hill Fault (part of the Mad River Fault zone), the Freshwater Fault, and the Little Salmon Fault are the three main faults within the Humboldt Bay region. They have north-northwest to northwest alignments and northeast dips. The Little Salmon Fault and the Table Bluff Anticline define the topographic high at the southwest boundary of the hydrographic region, and the Freshwater Fault separates the Central Belt Franciscan Complex from the younger rock formations in the central portion of the region.

Topography within the Quaternary – Tertiary overlap deposits is well dissected and of relatively low relief. The Wildcat Group and younger rocks in most of the Humboldt Bay Hydrographic Region are highly erodible, and fragments of the rock readily breakdown in the streambeds to sand, silt, and clay.

Published landslide maps indicate that both shallow- and deep-seated landslides exist within this HPA.

3.2.4.11 Eel River Hydrographic Region

The Eel River Hydrographic Region is approximately 205,000 acres and contains Quaternary-Tertiary overlap deposits and Quaternary age alluvium with Coastal Belt Franciscan Complex bedrock near the southern boundary of the region and Yager Terrane and Central Belt Franciscan bedrock under the eastern third of the region. Coastal Belt Franciscan bedrock underlies a very small portion of the Primary Assessment Area at the south end of the hydrographic region (Figure 3.2-1).

The geologic structure of the area follows the northwest trend of regional geologic structure. The Little Salmon Fault, which is known to be presently active, passes through the Eel River Hydrographic Region. The Freshwater Fault juxtaposes the Yager Terrane and Central Belt Franciscan bedrock and the Ferndale Fault defines the trace of the Van Duzen River at its confluence with the Eel River.

Topography within the Quaternary – Tertiary overlap deposits is highly variable and includes some steep slope segments. Published landslide maps indicate that both shallow and deep-seated landslides exist within this HPA.

3.2.4.12 Rain-on-Snow Areas Located Outside of the HPAs

Green Diamond ownership in the rain-on-snow areas outside the HPAs are shown on Figure 3.2-1. The following information is based on geologic maps published by CDMG (Strand, 1962; Redding, Sheet, and Wagner and Sucedo, 1987; Weed Sheet).

The ownership located to the northeast of the Primary Assessment Area along the Oregon-California border, is in a watershed that drains into the Middle Fork of the Smith River. This tract is predominantly underlain by Galice Formation bedrock of the Western Jurassic Belt of the Klamath Mountains Province. Galice Formation bedrock is composed of slate, partially serpentinized peridotite, meta-graywacke, and stretched pebble conglomerate. Along the western margin of this tract is metavolcanic bedrock of the Western Jurassic Belt. Elevations in this area range from approximately 3,000 feet to 4,000 feet. Topography is relatively steep and well dissected.

The ownership located east of Minor Creek and Redwood Creek near U.S. Highway 299 is predominantly underlain by the South Fork Mountain Schist geologic unit with areas of undifferentiated Central Belt Franciscan Complex bedrock and possibly limited occurrences of partially serpentinized ultra mafic bedrock. Elevations in the area range from 2,500 feet to 4,500 feet. Topography is variably steep and the drainage pattern appears to be structurally controlled (trellised).

The ownership located to the east of Pilot Creek and adjacent to the Mad River Hydrographic Region is in a watershed which drains to the Trinity River. This tract is predominantly underlain by the South Fork Mountain Schist geologic unit with areas of Upper Jurassic Age marine bedrock, Mesozoic granitic bedrock, and Cenozoic non-marine clastic bedrock. This area is included in the Franciscan Complex bedrock of the Coast Range Province. Elevations in the area range from approximately 2,000 feet to 5,000 feet. Topography is variably steep and the drainage pattern appears to be trellised.

Although no landslides were mapped on the geologic maps used to compile these descriptions, based on the mountainous terrane in these areas, it is reasonable to assume that there is the potential for both shallow and deep-seated landslides.

3.2.5 Mineral Resources

The description presented below is intended to provide a general overview of the known occurrences of commercial mineral resources and operating rock products facilities in the general vicinity of the Primary Assessment Area. Even though mineral resources and rock products of economic importance occur within the vicinity of Primary Assessment Area, extraction and processing of these resources would not be affected by the Proposed Action or the other alternatives. Green Diamond's rock pits are generally fewer that 2 acres in size; are located more than 100 and 75 feet from Class I and II streams, respectively; and are exempt from Surface Mining and Reclamation Act (SMRA) regulations. Therefore, a comprehensive assessment of the mineral resources and their extraction, processing, and use in the Primary Assessment Area was not undertaken for this EIS, and the information provided below is based on a survey of available literature only.

Currently, no commercial base metal (e.g., lead, zinc, copper) or precious metal (e.g., gold, silver) mineral production occurs in Del Norte or Humboldt counties, or on Green Diamond lands; however, commercial deposits of nickel and cobalt are in the vicinity of the Primary Assessment Area in Del Norte County. In 1977, a proposal for mining nickel and cobalt was submitted by Cal-Nickel Corporation. The company proposed mining of laterite deposits on Gasquet Mountain between the North Fork of the Smith River and Hardscrabble Creek (Institute for River Ecosystems at Humboldt State University, 1997). Because of economic considerations, the project is on hold, as are permitting and environmental issues (pers. com., Jay Sarina, Planning Division, County of Del Norte).

Historically, gold mining played an important role in the early economy of Del Norte and Humboldt counties (Ogle, 1953). Gold mining included numerous prospects of both placer and lode deposits. In addition to gold, other base and precious metals mined or prospected in the region include copper, chormite, manganese, zinc, and silver (CDMG Minefile Database, 2001). Manganese and copper were historically produced from the Franciscan Coastal Belt rocks and possibly from the Yager Formation (USFWS and CDF, 1998).

Historical mining activity in the Primary Assessment Area also includes sand, gravel, and rock mining, with sand and gravel constituting the main non-fuel mineral resource (Ogle, 1953; Logan, 1947; Strand, 1962; Youngs and Kohler-Antablin, 1966; CDMG Minefile Database, 2001). These sources also identify historical stone production near the Primary Assessment Area, including rock and some small limestone bodies. Sand and gravel deposits occur along the current river and stream channels of the Primary Assessment Area. Additional sand and gravel is found in the Quaternary-Tertiary Wildcat Formation and the Hookton Formation. Building stone is and has historically been quarried from the Yager Formation and the Franciscan Coastal and Central Belt rocks. Limestone, presumably from the mélange of the Franciscan Central Belt rocks, was historically mined for Portland grade cement (Ogle, 1953; Strand, 1962).

Commercial deposits of sand, gravel, and stone exist in the vicinity of the Primary Assessment Area (CDMG Minefile Database, 2001). The geological formations that host these deposits are widespread in both Humboldt and Del Norte counties. At present, the CDMG Minefile Database lists 51 mining operations (rock quarries, sand and gravel operations, and borrow pits) in Humboldt County and 16 mining operations in Del Norte County (CDMG SMRA Eligible List as of 07/30/2001).

Green Diamond operates numerous rock quarries (borrow pits) within the Primary Assessment Area. These mining operations are used to supply surfacing or fill material for purposes of road construction and maintenance associated with timber harvesting and forest management. The pits are generally smaller than 2 acres in size and are located more than 100 and 75 feet from Class I and Class II watercourses, respectively. Because of their location and purpose (i.e., road construction and maintenance associated with timber harvesting and forest management), they are exempt from regulation under the Surface Mining and Reclamation Act of 1975 (SMARA) as administered by the State Mining and Geology Board. Two valid State of California permits for rock mining within the Primary Assessment Area are presently held by Mercer-Fraser.

Hydrocarbon resources (natural gas) exist near the southern border of the Primary Assessment Area. Currently, gas is produced in commercial quantities from an area known as the Tompkins Hill gas field. The Tompkins Hill field is located in the Eel River sedimentary basin; records indicate this basin has produced gas since 1937 (McLean, 1993). The gas comes from the sandstones of the Rio Dell Formation of the Wildcat Group. Production records for 1998 list gas production at Tompkins Hill at roughly 1.3 million cubic feet (DOGGR, 1998). Other gas fields in the area include the Table Bluff and Grizzly Bluff fields. However, both of these fields are listed by the Department of Conservation, Division of Oil, Gas, and Geothermal Resources as abandoned (DOGGR, 2001).

3.3 Hydrology and Water Quality

3.3.1 Introduction

This section provides descriptions of the watersheds within the HPAs, estuarine conditions for coastal areas, and baseline hydrology and water quality summaries. Watersheds may be wholly included in or split among several HPAs.

Logging, mining, road building, and grazing over the course of the last 100 years, combined with the local existence of steep slopes, unstable geologic formations, and seasonally intense precipitation, have produced runoff and erosion concerns for portions of the Primary Assessment Area. The north coast of California receives some of the heaviest precipitation in the state in the form of rain, snow, or both, depending on elevation.

Enhanced runoff, erosion, sedimentation, suspended sediments, and temperature are the chief water quality concerns of these coastal drainages. Some stream reaches and watersheds have been listed as impaired waterbodies by the RWQCB, and as such are subject to development of TMDLs. TMDLs will provide guidance for regulating suspended sediment concentrations or loads within certain project watersheds.

3.3.2 Watershed Characteristics

The regional geology, HPAs, and rivers in the vicinity of the Primary Assessment Area are shown on Figure 3.2-1 (Section 3.2, Geology, Geomorphology, and Mineral Resources). Key characteristics of these watersheds and HPAs are summarized in Table 3.3-1. Information specific to Green Diamond fee-owned lands within each HPA is also presented that typifies much of the remainder of the Primary Assessment Area for which detailed information is unavailable.

Currently, Green Diamond's fee-owned lands within the Primary Assessment Area contain more than 2,500 miles of Class I and II streams, 86 percent of which are Class II watercourses. In addition, Green Diamond's fee-owned lands contain about 4,000 miles of road within the HPAs, 85 percent of which are categorized as "seasonal."

TABLE 3.3-1
HPA Characteristics

HPA	HPA Acreage	Green Diamond Acreage Within HPA	Green Diamond Percentage	Green Diamond Road Miles	Class I Stream Miles	Class II Stream Miles	Class I and II Stream Miles
Smith River Hydrographic Region	181,999	44,177	24.3	422	65	287	352
Coastal Klamath Hydrographic Region	108,150	88,760	82.16	862	84	546	631
Blue Creek Hydrologic Unit	80,303	15,393	19.2	140	21	93	114
Interior Klamath Hydrographic Region	128,006	66,139	51.7	547	25	217	242
Redwood Creek Hydrologic Unit	188,335	33,038	17.5	290	30	158	187
Coastal Lagoons Hydrographic Region	53,592	39,981	74.6	394	31	237	268
Little River Hydrologic Unit	29,703	26,041	87.7	307	20	150	170
Mad River Hydrographic Region	119,686	49,376	41.3	433	42	256	298
North Fork Mad River Hydrologic Unit	31,416	28,209	89.8	297	18	152	169
Humboldt Bay Hydrographic Region	138,719	17,484	12.6	205	15	60	75
Eel River Hydrographic Region	205,160	7,933	3.9	98	3	38	41
Total	**1,265,069**	**416,532**	**32.9**	**3,996**	**355**	**2,192**	**2,547**

The HPA areas are part of nine contiguous coastal drainage basins that encompass approximately 13.7 million acres in northwestern California and southern Oregon. The size of the Primary Assessment Area and Green Diamond's fee ownership relative to the coastal basins directly correlates to the potential influence of Green Diamond's timber operations on these basins. Some of the HPAs represent a small proportion of the total area in the coastal basins of which they are a part, while others encompass the entire basin. Green Diamond's fee ownership in the largest coastal basins (Klamath, Smith, and Eel Rivers) is concentrated in HPAs near the coast and is very small relative to total basin size, limiting the influence of Green Diamond's operations on these watersheds. Upstream factors including dams, water diversions, development, and other commercial land uses (e.g., agriculture and non-Green Diamond timber management activities) further reduce the relative impact of Green Diamond's operations on these drainages. Some of the smaller coastal basins, in contrast, are largely owned by Green Diamond, and Green Diamond's management activities may be the main human-caused influence within these drainages.

3.3.3 Climate

The climate of the HPAs is highly variable, dependent on elevation and slope, but is generally representative of the cool, rainy climate of the coastal area of northern California. The general climatic conditions influence the hydrology of the HPAs and associated watersheds and are summarized by HPA below.

Additional Green Diamond areas to be evaluated as part of Alternative C are described as rain-on-snow areas and are generally higher in elevation than most of the HPA areas described below. The rain-on-snow Green Diamond lands range in elevation from 2,400 feet to 5,000 feet. Precipitation in these areas occurs mostly as snow at elevations above 3,500 feet and ranges from 60 inches to 70 inches per year.

3.3.3.1 Smith River Hydrographic Region

This hydrographic region is located in one of the wettest areas of California. Average annual rainfall varies from about 60 inches at Point St. George to more than 125 inches at higher inland areas. The precipitation is orographic in nature, increases with elevation, and is usually greater on the windward (southwest) slopes. About 75 percent of the precipitation occurs between November 1 and March 31 (90 percent between October 1 and April 30). Average annual snowfall in the unit ranges from 28 inches at elevations of 1,700 feet ASL (Elk Valley) to 126 inches at 2,420 feet ASL (Monumental).

The climate in this area is primarily influenced by marine air masses and cold air drainage from higher elevations. Occasionally, the climate is influenced by drier air masses associated with east winds.

3.3.3.2 Coastal Klamath Hydrographic Region

The large size of the Klamath basin and its geographic differences results in a wide range of climatic conditions. For the entire basin, the weather can be generalized as having dry summers with hot daytime temperatures and wet winters with low to moderate temperatures. Peak air temperatures occur during July with a monthly average maximum of 18.3°C for the coast and 35°C inland. Precipitation is seasonal, with approximately 90 percent falling between October and March. Annual amounts vary from 20 inches to more than 80 inches, depending on location. High intensity rainfall occurs December through February and may cause flooding at times. Snow occurs at higher elevations and some areas receive up to 80 inches annually.

3.3.3.3 Blue Creek Hydrologic Unit

Precipitation in the Blue Creek headwaters averages 100 inches annually, 75 percent of which falls between November and March (Helley and LaMarche, 1973, as cited in Voight and Gale, 1998). Air temperatures in the region are mainly affected by the coastal marine climate, with daily high temperatures ranging from 4.4 - 21.1°C annually. During the summer the climate is moderated by coastal fog, which reduces solar radiation and contributes moisture by fog drip.

3.3.3.4 Interior Klamath Hydrographic Region

The large size of the Klamath basin and its geographic differences result in a wide range of climatic conditions. In the interior (e.g., South Fork Trinity sub-basin), the climate is generalized by hot, dry summers and cool, wet winters. The average annual precipitation for the South Fork Trinity sub-basin is 30 to 60 inches, depending on altitude and distance from the Pacific Ocean. Most precipitation falls between November and March, with negligible amounts in localized areas between June and September. Snow is a major component of the annual precipitation in higher elevations.

3.3.3.5 Redwood Creek Hydrologic Unit

Precipitation in the Redwood Creek basin is highly seasonal, with 90 percent occurring between October and April. The annual average for the basin is almost 80 inches, with more than 90 inches occurring in localized areas. December is usually the wettest month with about 17 percent of the annual total.

3.3.3.6 Coastal Lagoons Hydrographic Region

A coastal weather pattern is typical for the lagoons. Summers are mild in temperature with a marine fog layer commonly occurring; winters are cooler. The average annual rainfall is 40 to 60 inches, with heavier amounts falling in the more inland areas. Most of the precipitation falls between October and April.

3.3.3.7 Little River Hydrologic Unit

The Little River drainage has a weather pattern similar to most northern California coastal watersheds, typically with wet winters and dry summers. At least 80 percent of the precipitation occurs between November and April. The coastal area receives about 50 inches annually, whereas interior parts of the watershed receive over 80 inches annually. Most of the precipitation falls as rain, although snowfall occurs at the higher elevations. Coastal marine fog is common during the summer months.

3.3.3.8 Mad River Hydrographic Region

In the Mad River basin, 75 percent of the annual precipitation occurs between November and March. Annual precipitation levels range from around 40 inches at the coast to greater than 70 inches in the central basin. The basin average is approximately 63 inches. In the upper basin, snow averages 23 inches annually and usually occurs above 3,000 feet, but snow levels may occasionally drop to as low as 1,000 feet ASL.

3.3.3.9 North Fork Mad River Hydrologic Unit

The average daily air temperature in the North Fork Mad River Hydrologic Unit ranges from a high of 16.7°C during August to a low of 4.4°C in January. The average annual precipitation in the hydrologic unit ranges from 60 to 80 inches, with rainfall increasing inland. Most precipitation occurs between October and May. Snow usually occurs above 3,000 feet ASL, but snow levels may occasionally drop to as low as 1,000 ASL.

3.3.3.10 Humboldt Bay Hydrographic Region

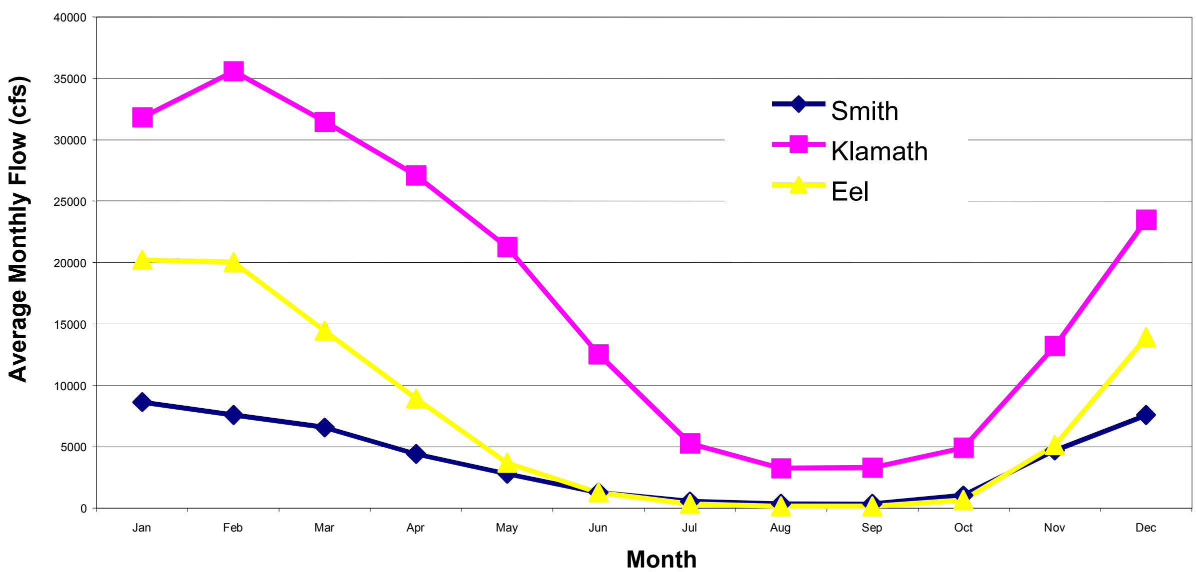
The watersheds that drain into Humboldt Bay are influenced by the coastal weather patterns of northern California. Typically, the majority of precipitation falls as rain between November and April with snowfall occurring sporadically at higher elevations. Coastal areas around Eureka receive about 35 to 40 inches of rain annually, whereas inland areas of the basin may receive 60 inches or more per year. During the summer the climate is moderated by coastal fog, which reduces solar radiation and contributes moisture by fog drip.

3.3.3.11 Eel River Hydrographic Region

Like the majority of northern California, climate in the Eel River basin is characterized by wet winters and dry summers. Nearly 80 percent of the annual precipitation falls between November and April. The average annual precipitation varies from less than 40 inches in the Eel River Plain and Round Valley to more than 110 inches in the Bull Creek headwaters. The average annual precipitation for the entire Eel River basin is about 60 inches. Fog drip during the summer months is a source of precipitation not included in annual totals. The dense, often persistent, band of marine fog usually extends 20 to 30 miles inland. Measurements in the Bear River Ridge revealed fog drip accumulations of 12 inches in open areas and 8.5 inches under forest canopy.

3.3.4 Baseline Hydrologic Data

Peak flows in the northern coastal watersheds usually occur during winter storms in January. The Eel, Smith, and Klamath Rivers had mean peak daily flows of 395,000 cubic feet per second (cfs), 75,500 cfs, and 397,000 cfs, respectively, for January flows during 1974 and 1975 storms. The typical annual pattern of flows for these rivers is shown on Figure 3.3-1. Note that the streams are markedly seasonal with extended low flow periods during the summer and fall. These rivers are the major project drainages and are shown as examples of typical seasonal flow patterns.



Period of Record: Smith 10/01/1931 to 9/30/1999
Klamath 10/01/1910 to 9/30/1926, 10/01/1950 to 10/29/1995, 10/01/1997 to 9/30/1999
Eel 10/01/1910 to 9/30/1914, 10/01/1916 to 9/30/1999

FIGURE 3.3-1
Average Monthly Flows of Project Rivers

3.3.5 Water Quality

Most surface waters in the Primary Assessment Area have not been sampled for water quality, but key constituents of concern (temperature, suspended sediment, turbidity) have been analyzed from a number of locations. Values generally meet or exceed minimum RWQCB Basin Standards, although some of the streams are listed as impaired under Section 303(d) of the CWA. (Green Diamond's proposed AHCP/CCAA is not intended to address Federal CWA/TMDL requirements.) The list of waterbody impairments is shown in Table 3.3-2. The causes for impairment in these streams vary, but include such factors as:

- Nonpoint-source erosion/siltation
- Rangeland
- Silviculture
- Loss of riparian vegetation
- Logging roads
- Streambank destabilization
- Erosion/siltation

TABLE 3.3-2
Waterbody Impairment and Beneficial Uses for Impaired Water Bodies in Primary Assessment Area Watersheds

Watershed	Listed Impairment	Existing Beneficial Uses[a]
Klamath River	Temperature, nutrients, dissolved oxygen	MUN, AGR, GWR, FRSH, NAV, REC1, REC2, COMM, WARM, COLD, MIGR, SPWN, EST, AQUA
Redwood Creek[b]	Sediment	MUN, AGR, IND, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN, SHELL, EST
Mad River	Sediment, turbidity	MUN, AGR, IND, PROC, POW, REC1, REC2, COMM, WARM, COLD, WILD, RARE, MIGR, SPWN, EST, AQUA
Eel River	Sediment, temperature	MUN, AGR, IND, GWR, NAV, POW, REC1, REC2, COMM, WARM, COLD, WILD, RARE, MIGR, SPWN, EST, AQUA
Van Duzen River	Sediment	MUN, AGR, IND, REC1, REC2, COMM, COLD, WILD, RARE, MIGR, SPWN, AQUA
Freshwater Creek	Sediment	MUN, COMM, EST
Elk River	Sediment	MUN, COMM, EST

[a] Beneficial use codes are MUN municipal and domestic, AGR agricultural, IND industrial, PROC industrial process, GWR groundwater recharge, FRSH freshwater replenishment, NAV navigational, POW hydropower generation, REC1 body contact recreation, REC2 non-contact recreation, COMM commercial and sport fishing, WARM warm freshwater habitat, COLD cold freshwater habitat, WILD wildlife habitat, RARE threatened or endangered species, MIGR migration of aquatic organisms, SPWN fish spawning, SHELL shellfish, EST estuarine habitat, AQUA aquaculture.

[b] Planning and restoration for Redwood Creek will be with the National Park Restoration Plan.

General characteristics of Primary Assessment Area streams can be derived from U.S. Geological Survey (USGS) stream monitoring records for the major rivers. Table 3.3-3 shows mean daily ranges of temperature, turbidity, and conductivity for the Smith, Klamath, and Eel Rivers near their mouths.

TABLE 3.3-3
Range of Mean Daily Water Quality Values for Three Primary Assessment Area Rivers

Parameter	Klamath River Near Klamath	Smith River at Crescent City	Eel River at Scotia
Daily mean temperature range (°C)	4 - 27.5	3 - 21.5	5 - 23.5
Daily mean turbidity range (NTU)	0 - 95	0.2 - 12	0 - 380
Daily mean conductivity range (µmhos/cm)	95 - 250	63 - 159	90 - 351
Period of record	1,973 - 1,995	1,973 - 1,993	1,973 - 1,995

Source: USGS stream monitoring records.

The records of high turbidity and low conductivity were all found in winter months during days of high runoff. High temperatures in late summer were all during low flow periods.

In addition to the long-term records from the lower elevation gaging stations, water temperature monitoring has been conducted since 1994 in the various HPAs. As of the end of the year 2000, more than 400 temperature profiles have been recorded at 111 Class I (fishbearing) stream sites and 210 profiles at 70 sites in Class II streams with the following objectives:

- Document the highest 7DMAVG (the average of all temperatures recorded over a 7-day period) and daily fluctuations for each site.
- Determine seasonal maximum water temperatures.
- Identify stream reaches with temperatures that may exceed the thresholds of any of the covered species.

In addition to documentation of average stream temperatures and species-specific temperature thresholds, relationships were developed between temperature and drainage area as a means of accounting for the natural variation in water temperatures. These regression relationships yielded confidence limits of temperature based on drainage basin area. Individual values greater than those limits were viewed as possible locations of temperature exceedances for aquatic species of concern. Summary descriptions of temperatures relative to exceedance thresholds for specified aquatic species of concern are provided below for purposes of defining temperature variability between lower and upper watershed reaches within each HPA. A complete description of the temperature monitoring program, that includes site locations, summarized data, and appropriate temperature thresholds for salmonids can be found in Appendix C-5 of the proposed AHCP/CCAA. Monitoring data on suspended sediments and turbidity are not available for watershed reaches in each HPA.

3.3.5.1 Smith River Hydrographic Region

Summer water temperatures within the Smith River Hydrographic Region have been below the recommended NMFS Maximum Weekly Average Temperature (MWAT) threshold value for juvenile coho of 17.4°C (NMFS, 1997) at every monitored location throughout 6 years of temperature monitoring. The average 7DMAVG for all 61 Class I temperature profiles recorded since 1994 was 14.4°C. The highest recorded 7DMAVG value was 17.3°C in lower Goose Creek in 1997. Water temperature does not appear to be a limiting factor for salmonids in the Smith River Hydrographic Region.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 94 of the 113 recorded profiles (83 percent). The highest 7DMAVG recorded was 17.3°C and the average 7DMAVG for all summer temperature profiles was 13.6°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Smith River Hydrographic Region at most sites and most years of monitoring.

3.3.5.2 Coastal Klamath Hydrographic Region

Summer water temperatures within the Coastal Klamath Hydrographic Region have been above the recommended NMFS threshold value for juvenile coho of 17.4°C in only two of the 67 recorded Class I temperature profiles. 7DMAVG values of 17.4°C and 17.6°C were recorded in lower Turwar Creek in 1994 and 1997, respectively. The average 7DMAVG for all 67 Class I temperature profiles recorded since 1994 was 15.0°C. Water temperature does not appear to be a limiting factor for salmonids in the Coastal Klamath Hydrographic Region.

Maximum temperatures at the monitoring sites (Class I and II streams) have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 53 of the 75 recorded profiles (71 percent). The highest 7DMAVG recorded in headwater streams was 17.6°C and the average 7DMAVG for all headwater summer temperature profiles was 14.8°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Coastal Klamath Hydrographic Region at most sites and most years of monitoring.

3.3.5.3 Blue Creek Hydrologic Unit

Summer water temperatures within the Blue Creek Hydrologic Unit have been above the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C in only one of the 23 recorded Class I temperature profiles. A 7DMAVG values of 18°C was recorded in Blue Creek in 1997. The average 7DMAVG for all 23 Class I temperature profiles recorded since 1994 was 15.1°C. Water temperature does not appear to be a limiting factor for salmonids in the Blue Creek Hydrologic Unit.

Maximum temperatures at the headwaters monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 19 of the 28 recorded profiles (68 percent). The highest 7DMAVG recorded in headwater streams was 18°C and the average 7DMAVG for all summer temperature profiles was 15.0°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Blue Creek Hydrologic Unit at most sites and most years of monitoring.

3.3.5.4 Interior Klamath Hydrographic Region

Summer water temperatures within the Interior Klamath Hydrographic Region have been above the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C in only three of the 23 recorded Class I temperature profiles. The average 7DMAVG for all Class I temperature profiles recorded since 1994 was 14.8°C. Water temperature does not appear to be a limiting factor for salmonids in Interior Klamath Hydrographic Region.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 20 of the 30 recorded profiles (67 percent). The highest 7DMAVG recorded in headwater streams was 20.1°C, and the average 7DMAVG for all headwater summer temperature profiles was 14.6°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Interior Klamath Hydrographic Region at most sites and most years of monitoring.

3.3.5.5 Redwood Creek Hydrologic Unit

Summer water temperatures within the Redwood Creek Hydrologic Unit have been above the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C in 4 of the 15 recorded Class I temperature profiles. A 7DMAVG value of 22°C was recorded in Redwood Creek at Panther in 2000. The other occurrences of 7DMAVG temperatures above 17.4°C have also been in the mainstem of Redwood Creek and lower Coyote Creek. The average 7DMAVG for all Class I temperature profiles recorded since 1994 was 15.7°C. Summer water temperature may be a limiting factor for salmonids in Redwood Creek itself, while temperatures in tributaries to Redwood Creek appear to remain relatively cool through the summer.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 29 of the 37 recorded profiles (78 percent). The highest 7DMAVG recorded in all streams was 22°C, and the average 7DMAVG for all headwater summer temperature profiles was 14.7°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Redwood Creek Hydrologic Unit at most sites and most years of monitoring.

3.3.5.6 Coastal Lagoons Hydrographic Region

Summer water temperatures within the Coastal Lagoons Hydrographic Region have been below the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C at all Class I sites throughout 6 years of temperature monitoring. The highest recorded 7DMAVG value was 16.1°C in lower Maple Creek in 2000. The average 7DMAVG for all 43 Class I temperature profiles recorded since 1994 was 14.4°C. Water temperature does not appear to be a limiting factor for salmonids in the Coastal Lagoons Hydrographic Region.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 61 of the 65 recorded profiles. The highest 7DMAVG recorded in all streams was 16.5°C, and the average 7DMAVG for all summer temperature profiles was 14.0°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Coastal Lagoons Hydrographic Region.

3.3.5.7 Little River Hydrologic Unit

Summer water temperatures within the Little River Hydrologic Unit have been at the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C twice throughout 6 years of temperature monitoring. A 7DMAVG value of 17.4°C was recorded in the lower Little River in 1996 and 2000. The average 7DMAVG for all 44 Class I temperature profiles recorded since 1994 was 14.9°C. Water temperature does not appear to be a limiting factor for salmonids in the Little River Hydrologic Unit.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 58 of the 72 recorded profiles (81 percent). The highest 7DMAVG recorded in headwater streams was 17.4°C, and the average 7DMAVG for all headwater summer temperature profiles was 14.0°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Little River Hydrologic Unit at most sites and most years of monitoring.

3.3.5.8 Mad River Hydrographic Region

Summer water temperatures within the Mad River Hydrographic Region have been above the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C eight times at three sites: middle Canon Creek in 2000, and lower Canon Creek between 1996 and 2000, and Boulder Creek in 1997 and 1998. The highest recorded 7DMAVG was 18.8°C in lower Canon Creek in 1997. The average 7DMAVG for all 37 Class I temperature profiles recorded since 1994 was 16.1°C. Summer water temperature may be a limiting factor for salmonids in portions of the Mad River Hydrographic Region.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 68 of the 90 recorded profiles (76 percent). The highest 7DMAVG recorded in all streams was 18.8°C, and the average 7DMAVG for all headwater summer temperature profiles was 12.9°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Mad River Hydrographic Region at most sites and most years of monitoring.

3.3.5.9 North Fork Mad River Hydrologic Unit

Summer water temperatures within the North Fork Mad River Hydrologic Unit have been above the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C in one reach, the lower North Fork Mad River, in every year it was monitored (1994-2000), with 7DMAVG values ranging from 17.7°C in 1994 to 19.7°C in 1996. The average 7DMAVG for all 39 Class I temperature profiles recorded since 1994 was 15.3°C. Temperatures at all other sites in this HPA have been below the recommended NMFS threshold for juvenile coho except for site 1a on the North Fork Mad River in 1998. Summer water temperatures may be a limiting factor for salmonids in the lower mainstem North Fork Mad River, but do not appear to be limiting in the upper North Fork Mad River or tributaries to it.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 39 of the 52 recorded profiles (75 percent). The highest 7DMAVG recorded in streams was 19.7°C, and the average 7DMAVG for all summer temperature profiles was 14.8°C. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the North Fork Mad River Hydrologic Unit at most sites and most years of monitoring.

3.3.5.10 Humboldt Bay Hydrographic Region

Summer water temperatures within the Humboldt Bay Hydrographic Region have been above the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C twice at lower Salmon Creek throughout 6 years of monitoring. The recorded 7DMAVG values at the site were 18.1°C in 1997 and 17.4°C in 1998. The average 7DMAVG for all 35 Class I temperature profiles recorded since 1994 was 14.7°C. Summer water temperatures do not appear to be a limiting factor for salmonids in the Humboldt Bay Hydrographic Region.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in 28 of the 35 recorded profiles (80 percent). The highest 7DMAVG recorded in Class I streams was 18.1°C, and the average 7DMAVG for all headwater summer temperature profiles was 14.7°C. No Class II sites have been monitored to date. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Humboldt Bay Hydrographic Region at most sites and most years of monitoring.

3.3.5.11 Eel River Hydrographic Region

Summer water temperatures within the Eel River Hydrographic Region have been below the recommended NMFS threshold MWAT value for juvenile coho of 17.4°C at every site throughout 6 years of monitoring. The highest recorded 7DMAVG value was 16.6°C in Stevens Creek in 2000. The average 7DMAVG for all 12 Class I temperature profiles recorded since 1994 was 14.7°C. Summer water temperatures do not appear to be a limiting factor for salmonids in the Eel River Hydrographic Region.

Maximum temperatures at the monitoring sites have been below the upper limiting temperatures for tailed frogs (18.5°C) and the thermal stress threshold for southern torrent salamanders (17.2°C) in all but two of the 12 recorded profiles. The highest 7DMAVG recorded in Class I streams was 16.6°C, and the average 7DMAVG for all summer temperature profiles was 14.7°C. No Class II sites have been monitored to date. Water temperature does not appear to be a limiting factor for tailed frogs or southern torrent salamanders in the Eel River Hydrographic Region for most sites and years of monitoring.

3.4 Aquatic Resources

3.4.1 Introduction

This section describes fisheries and other aquatic resources occurring within the Primary Assessment Area and the additional 25,677 rain-on-snow acres under Alternative C that could potentially be affected by approval of the proposed Permits (Proposed Action), other action alternatives, or the No Action Alternative. Discussions focus on eight fish, four amphibian, and one reptile species occurring or potentially occurring within these areas that would be covered by one or more of the action alternatives. The distribution, status, life history and habitat requirements, and factors affecting populations of these 13 species are discussed in the following text.

This section also describes current, known aquatic habitat conditions within the Primary Assessment Area for each of the 11 HPAs previously described in Sections 3.2 and 3.3. In addition, this section summarizes general ecological implications of land management activities on aquatic habitat that have influenced, or could potentially influence, the affected environment. These descriptions are presented to inform the reader of general cause-effect relationships, and to develop the basis for assessing potential project effects on aquatic habitat and the covered species in Chapter 4, Environmental Consequences, of this document.

3.4.2 Covered Species

3.4.2.1 Background

Table 3.4-1 lists the common and scientific names of the eight fish species, four amphibian species, and one reptile species covered under the various action alternatives, and their status under the Federal and State ESAs. The designation in Table 3.4-1 of individual ESUs/DPSs of steelhead and coho and Chinook salmon as individual species is consistent with language in the Federal ESA. An ESU must be substantially reproductively isolated from other conspecific population units, and it must contribute substantially to ecological/genetic diversity of the biological species as a whole. The DPS policy adopts criteria similar to, but somewhat different from, those in the ESU policy for determining when a group of vertebrates constitutes a DPS: the group must be discrete from other populations, and it must be significant to its taxon. A group is discrete if it is “markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, and behavioral factors.” Using the DPS policy, resident rainbow trout are considered “markedly separated” from the anadromous form and are not included in the current steelhead listing (71 FR 834). Measures to minimize and mitigate the potential impacts of incidental take on the covered species are evaluated in Chapter 4, Environmental Consequences. These measures focus on assessing, conserving, and monitoring the populations and habitats of the species covered under the various alternatives. The mitigation measures, supporting analysis, and related authorizations also provide the basis for Green Diamond to comply with any requirements of the CFPRs relating to the ESA and the covered species.

3.4.2.2 General Information

Distribution. The 13 fish, amphibian, and reptile species discussed in this section occupy a wide range of stream reaches based on their specific habitat requirements and biological adaptations. Because of this diversity, they are dependent on a variety of stream habitats. Some larger streams may be used by all of the species, while smaller tributaries may be used by all, some, one, or none of the species. In general, Chinook salmon are distributed from the coast to low-elevation streams a short distance inland. Coho salmon venture farther inland to higher elevations than Chinook salmon. Steelhead, rainbow trout, and coastal cutthroat trout are distributed from the coast to higher-elevation areas farther inland than either Chinook or coho salmon.

The tidewater goby is found in estuarine environments and rarely ventures far upstream into fresh water.

Many of the amphibian and reptile species are found at relatively low elevations; however, tailed frogs are generally found at higher elevations and farther inland from the coast than the fish species. Torrent salamanders are found at even higher elevations than tailed frogs.

TABLE 3.4-1
Federal and State Protective Status of Fish, Amphibian, and Reptile Species Covered Under the Action Alternatives

Species Common Name	Scientific Name	Coverage	Federal Status	State Status
Fish				
Southern Oregon/Northern California Coasts coho salmon ESU	*Oncorhynchus kisutch*	P,A,B,C	FT[a]	ST
Klamath Mountains Province steelhead ESU	*Oncorhynchus mykiss*	P,B,C	None[b]	None
Northern California steelhead DPS	*Oncorhynchus mykiss*	P,A,B,C	FT[b]	None
California Coastal Chinook salmon ESU	*Oncorhynchus tshawytscha*	P,A,B,C	FT[c]	None
Southern Oregon and Northern California Coastal Chinook salmon ESU	*Oncorhynchus tshawytscha*	P,B,C	None[c]	None
Upper Klamath-Trinity Rivers Chinook salmon ESU	*Oncorhynchus tshawytscha*	P,B,C	None[c]	None
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	P,B,C	FSS[d]	CSC
Rainbow trout [e]	*Oncorhynchus mykiss*	P,B,C	None	None
Tidewater Goby	*Eucyclogoloius newbenyi*	C	FE	CSC
Amphibians				
Southern torrent salamander	*Rhyacotriton variegatus*	P,B,C	None	CSC
Tailed frog	*Ascaphus truei*	P,B,C	None	CSC
Foothill yellow-legged frog	*Rana boylii*	C	FSS	CSC/CFP
Northern red-legged frog	*Rana aurora aurora*	C	FSS	CSC/CFP
Reptiles				
Western pond turtle	*Clemmys marmorata marmorata*	C	FSS	CSC/CFP

Coverage
P Proposed Action: Aquatic HCP/CCA
A Alternative A: Listed Species Only
B Alternative B: Simplified Prescriptions Strategy
C Alternative C: Expanded Species and Geographic Coverage

Federal Status
FE Federal endangered species
FT Federal threatened species
FSS Forest Service sensitive species

State Status
ST State of California threatened species
CSC CDFG Species of Special Concern
CFP California Fully Protected Species

[a] The Southern Oregon/Northern California Coasts coho salmon ESU was listed as threatened on May 6, 1997, and critical habitat was designated on May 5, 1999.

[b] The Klamath Mountains Province steelhead ESU did not warrant listing as of April 4, 2001. The Northern California steelhead DPS was listed as threatened on June 7, 2000, and critical habitat was proposed on December 10, 2004. Steelhead are the anadromous life history type of *Oncorhynchus mykiss* and are under the jurisdiction of the NMFS.January 5, 2006 (71 FR 834). Critical habitat for the Northern California steelhead ESU was designated on September 2, 2005 (70 FR 52488

[c] The California Coastal Chinook salmon ESU was listed as threatened September 16, 1999, and critical habitat was proposed on December 10, 2004. The Southern Oregon and Northern California Coastal Chinook salmon ESU did not warrant listing as of September 16, 1999. The Upper Klamath-Trinity Rivers Chinook salmon ESU did not warrant listing as of March 9, 1998.

[d] The NMFS determined that the Southern Oregon/California Coasts coastal cutthroat trout ESU did not warrant listing as of April 5, 1999. This species is now under the jurisdiction of the USFWS and a review of the status of this species is being conducted.

[e] Rainbow trout are the resident life history type of *Oncorhynchus mykiss* and are under the jurisdiction of the USFWS. Using the DPS policy, resident rainbow trout are considered “markedly separated” from the anadromous form and are not included in the current listing for steelhead (71 FR 834).

Status of Populations. Table 3.4-1 summarizes the status of the covered species for each of the action alternatives. The California Coastal Chinook salmon ESU, Southern Oregon/Northern California Coasts (SONCC) coho salmon ESU, and Northern California steelhead DPS are federally listed threatened species. Coho salmon north of Punta Gorda were listed as threatened under CESA on March 30, 2005. The NMFS determined that Federal listing was not warranted for the Klamath Mountains Province steelhead ESU (April 4, 2001, 66 FR 17845), the Southern Oregon and Northern California Coastal Chinook salmon ESU (September 16, 1999, 64 FR 50394), and the Upper Klamath-Trinity Rivers Chinook salmon ESU (March 9, 1998, 63 FR 11482). Cutthroat trout are now under the jurisdiction of the USFWS and undergoing a status review. Rainbow trout are the resident life history type of *Oncorhynchus mykiss* and are also under the jurisdiction of the USFWS and not included in the current steelhead DPS listings; this species is currently unlisted.

The tidewater goby is a federally listed endangered species. Southern torrent salamander, tailed frog, foothill yellow-legged frog, northern red-legged frog, and Western pond turtle have been designated as Federal species of concern by the USFWS.

Life History and Habitat Requirements. General life history and habitat requirements for the 13 fish, amphibian, and reptile species discussed in this section are provided below.

Fish. The eight fish species covered under the Proposed Action are members of the family Salmonidae and exhibit varying levels of anadromy. Anadromous fish rear in freshwater for varying lengths of time, migrate to the ocean where they grow and mature, then return to freshwater to spawn and complete their life cycle. Chinook and coho salmon are exclusively anadromous; all individuals migrate from freshwater streams to the ocean and return to spawn. Steelhead are the anadromous life form of rainbow trout. Cutthroat trout primarily exist as resident populations, but limited anadromy does occur. Coho and Chinook salmon die after spawning, while steelhead, rainbow trout, and coastal cutthroat trout may survive to spawn more than once. Key life history and habitat requirements of coho salmon, steelhead/rainbow trout, Chinook salmon, and coastal cutthroat trout are summarized in Table 3.4-2 and discussed below under the individual species' descriptions.

The anadromous (steelhead) and resident (rainbow trout) forms of *O. mykiss* are genetically indistinguishable, and the life history and habitat requirements of resident rainbow trout are similar to those of steelhead while in the freshwater phase.

Amphibians and Reptiles. Key life history and habitat requirements of the two amphibian species (southern torrent salamander and tailed frog) covered under the Proposed Action are summarized in Table 3.4-3 and discussed below under the individual species' descriptions. Amphibians breed in water and feed on land, in shrubs, or in trees. They occupy wetland, pond, riverine, and stream habitats as primary breeding areas. The general life history and habitat requirements of the additional amphibian species and the single reptile species that are only covered under Alternative C are summarized below under the individual species' descriptions.

TABLE 3.4-2
Key Life History and Habitat Requirements of Coho Salmon, Steelhead, Chinook Salmon, and Coastal Cutthroat Trout
(from Table 3-1 of Green Diamond's proposed AHCP/CCAA)

Characteristic	Coho Salmon	Steelhead/Rainbow Trout	Chinook Salmon	Coastal Cutthroat Trout
Spawning period (anadromous populations)	September to March, concentrated from January to February depending on rainfall and stream discharge	September to March depending on time of entry	September to January, concentrated from November to January depending on rainfall and stream discharge	December to May depending on time of entry
Spawning period (resident populations)	Not Applicable	September to April	Not Applicable	Spring or early summer
Spawning habitat				
Redd sites	Pool tails or slightly upstream	Pool tails, upper sections of watershed	Pool tails or slightly upstream	Pools tails with protective cover nearby
Water depth	0.2 to 0.5 m	0.1 to 1.5 m	0.5 to 7 m	0.1 to 1 m
Water velocity	0.3 To 0.5 m/sec	0.2 to 1.6 m/sec	0.2 to 1.9 m/sec	0.1 to 1 m/sec
Substrate size	1.3 to 15 cm	0.6 to 12.7 cm	1.3 to 15 cm	0.6 to 10.2 cm
Temperature	5.6°C to 13.3°C	5°C to 15°C	5.6°C to 13.9°C	5°C to 15°C
Incubation period	36 to 100 days depending on water temperature	19 to 80 days depending on water temperature	30 to 159 days depending on water temperature	40 to 50 days depending on water temperature

TABLE 3.4-2
Key Life History and Habitat Requirements of Coho Salmon, Steelhead, Chinook Salmon, and Coastal Cutthroat Trout
(from Table 3-1 of Green Diamond's proposed AHCP/CCAA)

Characteristic	Coho Salmon	Steelhead/Rainbow Trout	Chinook Salmon	Coastal Cutthroat Trout
Rearing habitat	Mix of pools and riffles with abundant instream and overhead cover Fry seek shallow water along stream margins, backwaters, and side channels Summer parr found mainly in pools Overwintering juveniles seek shelter from high flows in side channels, backwaters, under large boulders and woody debris Summer weekly average temperatures (MWAT) below 17.4°C	Fry tend to school and seek shallow water along stream margins Larger fry and juveniles maintain territories in pool and run habitat Summer weekly average temperatures (MWAT) below 17.4°C (NMFS recommendation for coho)	Fry seek cover in shallow water along channel margins or in low-velocity channel bottoms Overwintering juveniles seek shelter under large boulders and woody debris, and in side channels or other low-velocity refugia Fry young-of-the-year and yearling smolts also use estuarine habitat Summer weekly average temperatures (MWAT) below 17.4°C (NMFS recommendation for coho)	Fry seek low-velocity shallow water in stream margins, backwater pools, and side channels Large coho fry can force cutthroat fry into riffles Summer weekly average temperatures (MWAT) below 17.4°C (NMFS recommendation for coho)
Outmigration (for anadromous populations)	Juveniles usually remain in freshwater for 1 year Smolts outmigrate from late March to early June	Freshwater residence varies from 1 to 4 years, but 1 to 2 years is predominant in the Project Area	Downstream migration begins immediately after emergence (Late February to June) Estuarine residence varies, probably 1 to 6 weeks depending on conditions	Anadromous cutthroat smolt outmigrate at 1 to 6 years of age depending on estuarine conditions

TABLE 3.4-2
Key Life History and Habitat Requirements of Coho Salmon, Steelhead, Chinook Salmon, and Coastal Cutthroat Trout
(from Table 3-1 of Green Diamond's proposed AHCP/CCAA)

Characteristic	Coho Salmon	Steelhead/Rainbow Trout	Chinook Salmon	Coastal Cutthroat Trout
Other factors	Coho spawn after spending 1 to 2 years at sea; in California, most coho spawn at 3 years of age, with some males spawning at age 2 (jacks) All coho die after spawning	Steelhead spawn after 1 to 4 years at sea Adult steelhead may spawn more than once Summer-run steelhead are able to use habitat not accessible to fall/winter-run salmonids Anadromous (steelhead) and resident (rainbow trout) populations occur in the Action Area	Chinook spawn at 2 to 7 years of age; in California, 2- to 4-year-olds are most common Some males (jacks) spawn at age 1 or 2 All Chinook die after spawning	Resident and anadromous cutthroat use similar spawning habitat Non-migratory cutthroat live in isolated headwater tributaries Spawning tends to occur in 1st and 2nd order streams and isolated headwaters Cutthroat trout may spawn more than once

TABLE 3.4-3
Key Life History and Habitat Requirements of Southern Torrent Salamander and Tailed Frog
(from Table 3-2 of Green Diamond's proposed AHCP/CCAA)

Characteristic Habitat Requirements	Southern Torrent Salamander	Tailed Frog
General	Cold clear streams with a loose gravel substrate Areas with water seeping through moss-covered gravel Splash zones of waterfalls Uppermost portions of streams and headwater seeps	Cold clear streams with a boulder, cobble, or gravel substrate Upper portions of streams but overlapping upper extent of fish-bearing reaches
Adults	Interstices within gravel in streams and under objects along stream edges and in splash zone Usually remain within 1 m of flowing water	Streams and upland habitats along streambanks
Larvae	Interstices within gravel in streams	Attach selves to rocky substrates, primarily in riffles
Breeding period	Spring or early summer	Spring and fall
Metamorphosis of young	Probably 2 to 3 years	1 to 2 years (data specific to the Project Area)
Forage	Terrestrial and aquatic invertebrates	Terrestrial and aquatic invertebrates Tadpoles feed on diatoms
Other factors	Can persist in streams with subsurface flow during the dry summer season Generally are believed to have low dispersal capabilities	Predation by fish may limit distribution within lower sections of stream

Factors Affecting Populations. Water quality is an important habitat component for all fish species. Important water quality parameters for the covered salmonids and other fish species are temperature, sediment, and pollutants (Groot and Margolis, 1991; Rieman and McIntyre, 1993). Temperature affects fish growth, food supply, and the length of time required for egg incubation. Each life stage has preferred and optimal ranges of water temperature, with species' ranges often similar or overlapping. Activities that affect water temperature include those that reduce stream shading.

Stream sediment also is an important aspect of water quality. Too much sediment can result in stream-bottom embeddedness, which potentially limits the flow of well-oxygenated water among streambed gravels and cobbles. Reduced flow of well-oxygenated water through the stream bottom can affect egg incubation and survival, and the production of benthic invertebrates (insects), which are important fish foods (Groot and Margolis, 1991; Rieman and McIntyre, 1993).

Two other important factors can affect fish populations. These are the quantity and quality of physical habitat available and preferred by various species during different life stages, and the ability to access and use those habitats at different times of the year. Considerations include instream habitat characteristics, such as water depth and velocity, substrate, and the nature and complexity of overhead, shoreline, and bottom cover. Natural or artificial barriers that limit or prevent access to suitable habitat for spawning, rearing, migrations, and overwintering can adversely affect fish populations.

These same factors also directly or indirectly affect populations of the amphibian and reptile species covered under the various alternatives. In addition, since most species in this group breed exclusively in water, adjacent upland conditions have less of an impact on breeding habitat than riparian conditions. Additional information on each of the covered fish, amphibian, and reptile species is provided in the following text.

3.4.2.3 Coho Salmon: Southern Oregon/Northern California Coasts ESU

Distribution. Globally, coho salmon spawn in coastal watersheds in both Asia and North America. In Asia, they are distributed from Hokkaido, Japan to the Anadyr River in the former U.S.S.R. (Moyle, 1976; Hassler, 1987). In North America, coho salmon are distributed from Point Hope, Alaska south to the northern edge of Monterey Bay (Moyle, 1976). Along the North American coast, coho salmon are most abundant between southern Oregon and southeast Alaska. In California, coho salmon are the second most abundant of the five species of Pacific salmon. They are found in numerous coastal drainages from the Oregon/California border south to Waddell Creek and the San Lorenzo River in Santa Cruz County (Sandercock, 1991).

Status of Populations. NMFS published a proposed rule to list coho salmon as threatened in California and Oregon (July 25, 1995, 60 FR 38011). NMFS listed the SONCC coho salmon ESU as threatened (May 6, 1997, 62 FR 24588), and designated critical habitat for the SONCC coho salmon ESU (May 5, 1999, 64 FR 24049). This ESU extends from Cape Blanco, Oregon to Punta Gorda, California and overlaps the Primary Assessment Area. Critical habitat for the SONCC coho salmon ESU includes all river reaches accessible to listed coho salmon between Cape Blanco, Oregon and Punta Gorda, California, but excludes areas above specific dams or above longstanding, naturally impassable barriers. Critical habitat consists of the water, substrate, and adjacent riparian zone of estuarine and river reaches (including off-channel habitats). The location of coho salmon ESUs in the vicinity of the Green Diamond ownership is shown on Figure 3.4-1.

The State of California listed Central California coastal coho salmon on December 31, 1995 (CDFG, 2001). The State listed this species as endangered for waters south of San Francisco Bay only, which is south of the Primary Assessment Area. The State of California recently revised the listing status for coho salmon, listing the population segment south of Punta Gorda (including coho south of San Francisco Bay) as endangered and the population segment north of Punta Gorda to the northern California border as threatened.

Life History and Habitat Requirements. Coho salmon typically exhibit a relatively simple, 3-year life history pattern. Adults begin freshwater spawning migrations in late summer and fall, spawn from September to March, concentrated in January and February, then die. Eggs incubate in gravels of spawning redds for about 1.5 to 4 months before hatching as alevins. Alevins soon emerge from the gravel as young juveniles and begin active feeding.

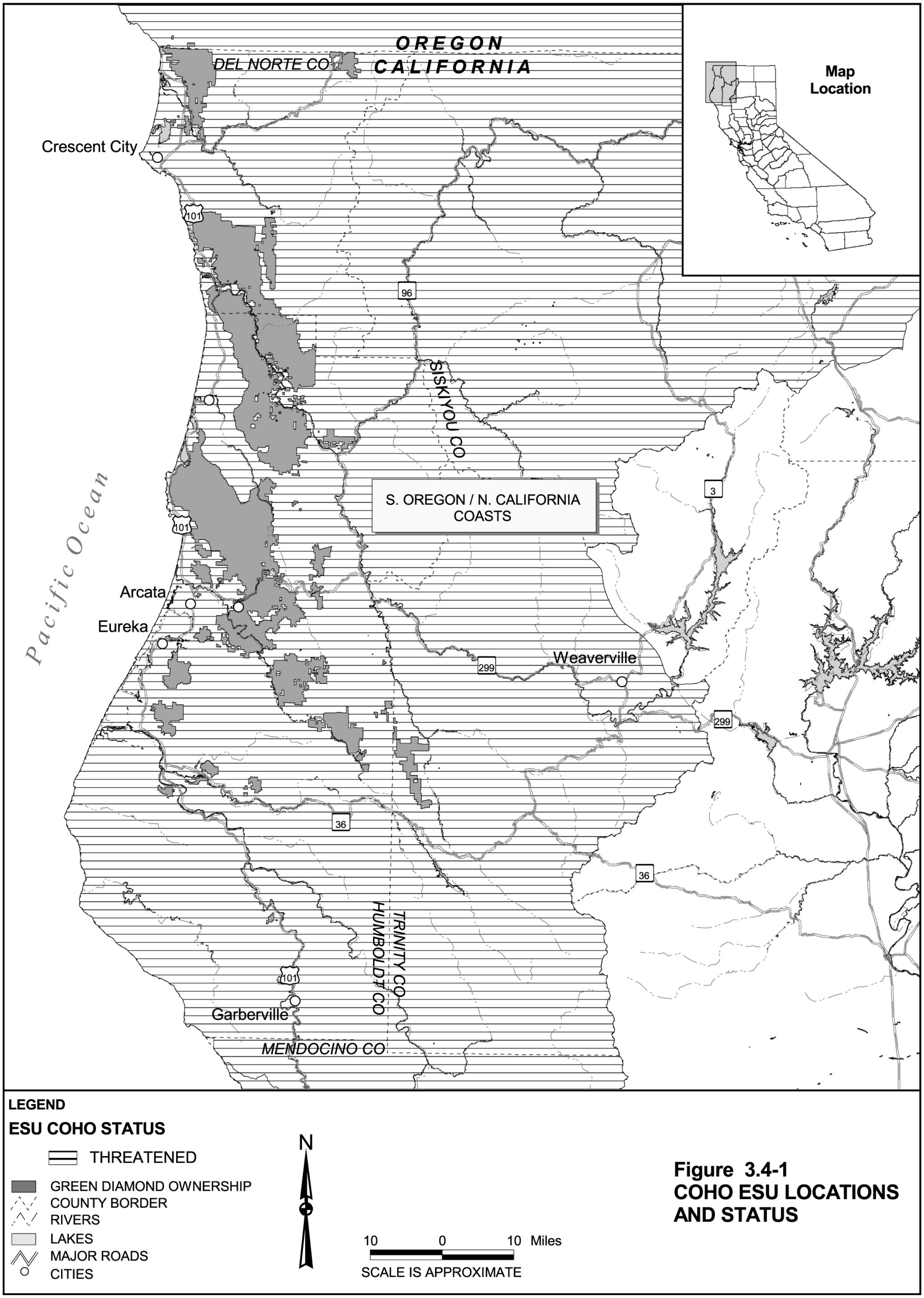


Figure 3.4-1
COHO ESU LOCATIONS AND STATUS

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Juveniles feed and grow in freshwater for up to 15 months before migrating to the ocean the following spring as 1+ age smolts. Juvenile coho salmon can rear for additional years in freshwater and outmigrate as 2+ or 3+ age smolts. Previous research found that all coho salmon in California outmigrate as 1+ smolts (Shapolov and Taft, 1954). In British Colombia and further north, coho salmon age 2+, and even age 3+ smolts are common (Sandercock, 1991). Recently, age 2+ coho outmigrants have been documented in Prairie Creek, California (Bell, 2001). Coho salmon generally rear for 2 years in the ocean before returning to their natal stream to spawn as 3-year old fish. A few may return to spawn after only 1 year in the ocean and are referred to as "jacks." Table 3.4-2 summarizes key life history and habitat requirements for coho salmon.

Factors Affecting Populations. NMFS has identified numerous human-caused and natural factors it believes have contributed to declines of coho salmon (July 25, 1995, 60 FR 38011). Threats to the SONCC coho salmon ESU are numerous and varied. Several human-caused factors, including habitat degradation, harvest, and artificial propagation, exacerbate the adverse effects of natural environmental variability caused by drought, floods, and poor ocean conditions. NMFS reported the major activities responsible for the decline of coho salmon in Oregon and California are logging, road building, grazing and mining activities, urbanization, stream channelization, dams, wetland loss, beaver trapping, water withdrawals, and unscreened diversions for irrigation (May 6, 1997, 62 FR 24588). Of recent note, poor water quality conditions in the Klamath River system in 2002 resulted heightened physiological stress on returning adult salmon, resulting in a significant disease induced die-off estimated at 344 wild adult coho salmon, 629 steelhead trout, and 33,527 adult Chinook salmon (Guillen 2002, 2003). Since this time poor water quality has also been implicated in increasing juvenile susceptability to native pathogens and is thought to be the cause significant juvenile outmigrant mortalities as well.

3.4.2.4 Chinook Salmon: California Coastal ESU, Southern Oregon and Northern California Coastal ESU, and Upper Klamath-Trinity Rivers ESU

Distribution. Native spawning populations of Chinook salmon are distributed along the Asian coast from Hokkaido, Japan, to the Anadyr River, and along the North American coast from central California to Kotzebue, Alaska (Moyle, 1976; Allen and Hassler, 1986; Healey, 1991). Chinook salmon spawning may occur from near tidewater in coastal watersheds to over 3,200 km upstream in headwaters of the Yukon River (Major et al., 1978).

Status of Populations. NMFS listed the California Coastal Chinook salmon ESU, which includes fall- and spring-run fish, as threatened (September 16, 1999, 64 FR 50394), and has proposed critical habitat for this ESU (December 10, 2004, 69 FR 71880). The California Coastal Chinook salmon ESU includes Chinook salmon populations from Redwood Creek in Humboldt County to the Russian River in Sonoma County, and, as such, overlaps the southern portion of the Primary Assessment Area. Proposed critical habitat for this ESU includes numerous river reaches and estuarine areas from Redwood Creek to the Russian River. These reaches and areas were identified through a process that considered historic and current utilization, current habitat quality, unique watershed and reach characteristics, the potential for restoration of degraded habitat, and the coextensive economic impacts associated with designation.

On September 16, 1999, NMFS determined that listing the SONCC Chinook salmon ESU was not warranted (64 FR 50394). The SONCC Chinook salmon ESU extends from Cape Blanco, Oregon to the Lower Klamath River (inclusive) and, as such, overlaps the northern portion of the Primary Assessment Area. The SONCC Chinook salmon ESU does not include Chinook salmon populations in the Klamath River Basin upstream from the confluence of the Klamath and Trinity Rivers. Chinook salmon populations upstream of these rivers' confluence comprise the Upper Klamath-Trinity Rivers ESU, which overlaps the eastern portion of the Primary Assessment Area. NMFS determined on March 9, 1998, that listing the Upper Klamath-Trinity Rivers ESU was not warranted (63 FR 11482). The location of Chinook salmon ESUs in the vicinity of the Green Diamond ownership is shown on Figure 3.4-2.

Life History and Habitat Requirements. Chinook salmon, like other salmon species, have complex life history characteristics and habitat needs because they are anadromous. Chinook salmon migrate extreme distances to spawn in the lower 48 states. The Primary Assessment Area only contains portions of rivers that are used for spawning and juvenile rearing by this species. Therefore, the following discussion of Chinook salmon only addresses those life history aspects.

Adult Chinook enter streams in the Primary Assessment Area from August through January. Spawning occurs in areas with clean large gravels, small cobbles, and sufficient flow to oxygenate eggs buried within the substrate. Spawning typically occurs in the fall, usually within 2 to 3 weeks after the fish reach their natal spawning grounds. Eggs incubate during the winter, then hatch from February through May. Fry remain in the gravel for about one month before emerging. Downstream migration begins immediately after emergence (late February to June). Estuarine residence varies from approximately 1 to 6 weeks, depending on conditions, before individuals move to the open ocean where they feed and rear (Moyle, 1976). Table 3.4-2 summarizes key life history and habitat requirements for Chinook salmon.

Factors Affecting Populations. Because of their complex life history and range of habitat requirements, salmon can be subjected to a wide variety of environmental conditions (both natural and influenced by man) that affect their populations. These include conditions in the ocean, along freshwater migration corridors, and on their spawning grounds. Factors commonly associated with impacted salmon populations include genetic introgression from hatchery fish, ocean habitat conditions, suitability of spawning substrate (clean gravels and cobbles), water temperature, instream flows, and over-fishing.

Although several factors are likely to have improved conditions for Chinook salmon in the California Coastal and SONCC Chinook salmon ESUs, habitat alterations in the coastal river drainages have contributed to the reduction in abundance and distribution of Chinook salmon in these ESUs. Examples of habitat alterations affecting Chinook salmon include: water withdrawal, conveyance, storage, and flood control (resulting in insufficient flows, stranding, juvenile entrainment, and increased stream temperatures); and logging and agriculture (resulting in loss of large woody debris, sedimentation, loss of riparian vegetation, and habitat simplification) (Spence et al., 1996; Myers et al., 1998; NMFS, 1998). Of recent note, poor water quality conditions in the Klamath River system in 2002 resulted heightened physiological stress on returning adult salmon, resulting in a significant disease

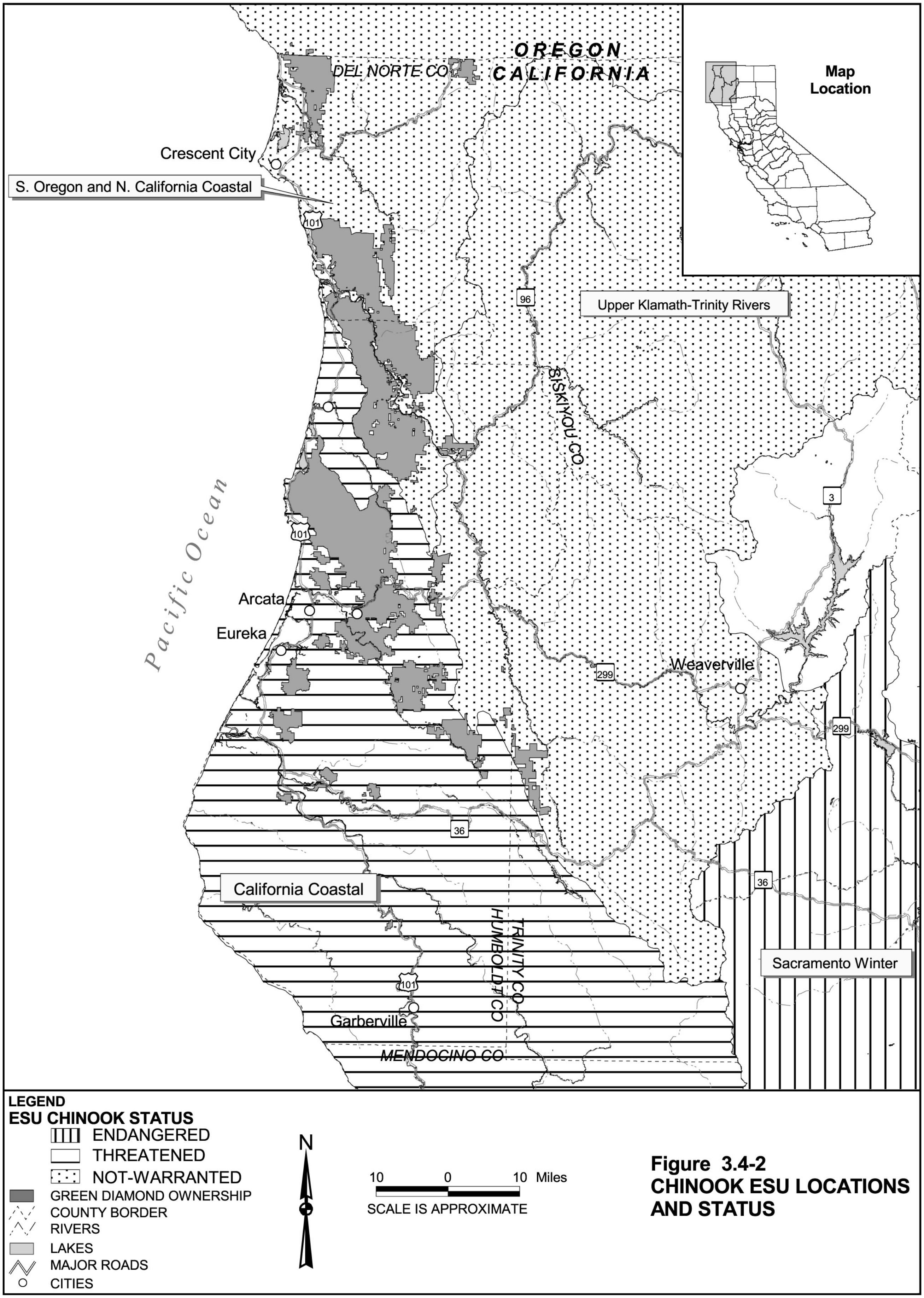

Figure 3.4-2
CHINOOK ESU LOCATIONS AND STATUS

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